URBAN GROWTH PATTERN AND SUSTAINABLE DEVELOPMENT: A COMPARATIVE STUDY OF MUNICIPALITIES IN THE SEOUL METROPOLITAN REGION

A Dissertation

by

SEUNGGEUN PAEK

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2006

Major Subject: Urban and Regional Science

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Approved by:

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ABSTRACT

Urban Growth Pattern and Sustainable Development: A Comparative Study of Municipalities in the Seoul Metropolitan Region. (August 2006)

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Chair of Advisory Committee: Dr. Arthur L. Sullivan

The main purpose of this study was to obtain a better understanding of the impact of urban growth and change on sustainability based on a comparative study of municipalities comprising Gyeonggi Province within the Seoul Metropolitan Region, Korea over the 1990-2000 period. To examine the impact of urban growth and change on sustainability, this study selected 38 sustainability indicators (population density, waste recycling rate, time spent commuting, etc.) and then measured progress towards sustainability in 31 study areas for the years 1990, 1995 and 2000. Data for this study were drawn from the 1990-2000 censuses and local government publications. Statistical methods such as t-test, analysis of variance and factor analysis were used to answer the research questions.

This study led to five major findings. First, the study areas with higher densities showed the lower mean values of sustainability. This result implies that increased density does not necessarily result in improved sustainability. Second, the level of sustainability has increased over time in urban areas with green belt, but the mean differences were not statistically significant. On the contrary, the level of sustainability continued to decline in their surrounding areas over the study period. In particular, there was a significant decline between 1995 and 2000. Third, for the entire region, the overall level of sustainability has not improved over the study period. However, different trends of sustainability have emerged within different parts of the region. Fourth, there were significant differences in the mean values for the level of sustainability among three zones within the region. Overall, the level of sustainability was much higher in the nature preservation zone (where development projects are strictly controlled to protect natural resources) than in the growth management zone (where urban development consistent with the planned land use is allowed) and the over-concentration control zone (where further development is discouraged to control population growth) during the study period. Fifth, although there were some variations in elements affecting the pattern of sustainability for each year, key elements influencing the pattern of sustainability remained relatively stable over the study period.

DEDICATION

To my wife,

Eun-ju Lee

To my children,

Jae-won, Jong-min, and Jong-yoon

To Jesus

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I first and foremost express my sincere gratitude to Dr. Arthur L. Sullivan, the chair of my advisory committee, for his valuable guidance, motivation and constant encouragement. Without his genuine care and help, I could not have finished this dissertation. I also express my sincere gratitude to my advisory committee members, Dr. Donald A. Sweeney, Dr. Christopher D. Ellis and Dr. Robert S. Bednarz, for their precious suggestions, inspiration and encouragement throughout the course of this research.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

TABLE Page

TABLE Page

CHAPTER I

INTRODUCTION

1.1 Research Background

The concept of sustainable development became widely fashionable after 1987, when the World Commission on Environment and Development (WCED) published *Our Common Future*, or the Brundtland Report. According to the Brundtland Report, sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 43). The concept of sustainable development has emerged from a global political process that has tried to bring together, simultaneously, the most powerful needs of our time: (1) the need for economic development to overcome poverty; (2) the need for environmental protection; and (3) the need for social justice and cultural diversity to enable local communities to express their values in solving these issues (Newman & Kenworthy, 1999; WCED, 1987). The three pillars of sustainable development are economic development, environmental protection, and social equity (Agyeman & Evans, 2003; Campbell, 1996; World Bank, 2003).

The sustainability agenda is a major global issue and at the same time a local issue. Sustainability is seen to be meaningful and achievable only when it is practiced through local initiatives with global significance (Newman & Kenworthy, 1999). Stressing the

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This dissertation follows the style and format of *Journal of the American Planning Association*.

importance of communities' efforts in achieving sustainable development goals, Agenda 21, a comprehensive global blueprint for sustainable development adopted by the 1992 Earth Summit, recommends that local authorities adopt a local Agenda 21. Local Agenda 21 is community-based processes that (1) create a set of objectives that fulfill the sustainability agenda, (2) set out indicators that show how the progress toward sustainability can be measured, (3) assess how the city is performing on these criteria, and (4) provide policy options about how it can do better (Newman & Kenworthy, 1999; United Nations, 1992).

As the home for a growing percentage of the world's population, cities are a focus for the sustainability agenda, with enormous potential to generate change in how people use natural and human resources. Today, about 48 percent of the world's population is estimated to live in urban areas, and current projections indicate that the 50 percent mark will be crossed in 2007 (United Nations, 2004). Cities around the world are increasingly recognizing the need to pursue the sustainability agenda. One of the important ways of incorporating the concerns of sustainability into local planning programs is to develop and use indicators of sustainable development (Miller, 2004). Sustainable development indicators monitor progress towards sustainable development goals and provide a basis for assessing whether policies, plans and programs have the desired effects (Miller, 2004; United Nations, 2001). They can be used in planning, clarifying policy objectives and priorities, budgeting, communicating with the public, and raising awareness about the long-term implications of current decisions and behaviors as well as assessing performance (OECD, 1997, 2004; United Nations, 2001).

Since the 1992 Earth Summit recognized the importance of sustainability indicators in making informed decisions concerning sustainable development, attempts have been made to develop indicators of sustainable development and assess progress toward it at the international, national, and local levels. International organizations such as the United Nations (2001) and OECD (2000) played a critical role in developing indicators that assess progress at the national level. At the local level, some cities take initiatives in developing sustainability indicators as part of efforts to achieve urban sustainability: the Sustainable Seattle Indicators Project (Sustainable Seattle, 1998), the Central Texas Sustainability Indictors Project (Central Texas Sustainability Indictors Project, 2004); the Santa Monica Sustainable City Plan (City of Santa Monica, 2005a); the Portland Sustainability Initiative (City of Portland, 2000); the San Francisco Sustainability Plan (Sustainable City, 1996). Measuring and assessing progress toward sustainability contributes to producing information that policy makers require to evaluate programs and thus is essential to achieving sustainability.

1.2 Problem Statement

Cities are constantly involved in complex processes of change. A wide variety of social and economic factors affect the pattern of growth and change of cities: transportation and communication innovations (Castells, 1989; Hall & Pfeiffer, 2000; Hart, 2001; OECD, 2001; Sassen, 1998); internal and international migration (Thorns, 2002); public policies (Carruthers, 2002; Nelson & Duncan, 1995); and globalization of economic activities (Choe, 1998; Douglass, 2000; Marcotullio, 2003; Sassen, 1996). In particular, many of the cities in developing countries have been experiencing rapid urban growth and change and thus consider the challenge of sustainable development. The important thing is to alter negative changes to contribute to improving rather than degrading long-term human and ecological health (Sorensen, Marcotullio, & Grant, 2004). The pattern of urban growth and change, characterized by its speed, magnitude and intensity, poses both opportunities and constraints for sustainable development. To achieve sustainable growth and change of cities, it is important to examine the interactions of economic, environmental and social issues arising from urban growth and change.

The literature review found that further research on the relationship between urban growth and change patterns and sustainability is needed to guide urban growth and change in a sustainable manner. First, there is a need for an integrated approach to the impact of urban growth and change. Urban growth affects various aspects of cities, including land use, transportation, environment, economic growth, and housing (Brueckner, 2000; Carruthers & Ulfarsson, 2002; Kahn, 2005; Smart Growth BC, 2001). Therefore, in order to better understand the impacts of urban growth, an integrated approach is needed in that urban growth has both positive and negative consequences for cities in various fields. Assessing urban sustainability deals with economic, environmental and social aspects of cities in a balanced way (Campbell, 1996; Fung & Kennedy, 2005; Maclaren, 1996). In this respect, an empirical study of the impact of urban growth and change on sustainability offers an analysis framework for dealing with the impacts of urban growth and change in a holistic, integrated manner.

Second, there is a need for an increased understanding of the causal relationship between urban growth patterns and sustainable development through a comparative analysis of cities with different urban growth patterns over time. The patterns of urban growth have an effect on determining urban sustainability (Kahn, 2005). In general, different patterns of urban growth are expected to generate different impacts. In a situation of rapid urban growth and change in developing countries in particular, there is an increasing need for an investigation that traces the impact of urban change on sustainability through time by comparing cities to provide valuable information needed for sustainable urban management (Drakakis-Smith, 1996). More attention must be paid to the patterns and processes of urban growth in order to avoid negative, unintended consequences of rapid urbanization (Redman, 2005). To find empirical evidence of the sustainability effects of urban growth patterns through a comparative analysis will contribute to identifying the pros and cons of each different urban growth pattern in terms of sustainability, identifying the factors influencing such a process, and thus help to incorporate sustainability issues into the planning process. However, lacking are empirical tests of specified hypotheses on the relationship between urban growth patterns and sustainability. Evidence from test of specified hypotheses on the relationship between urban growth patterns and sustainability needs to be added to understand the various contexts in which urban growth patterns and urban sustainability interact.

Third, there is a need for a better understanding of the relationship between the effectiveness of cities' growth control efforts and the efforts of their surrounding metropolitan areas from a sustainability perspective. There have been questions concerning the effects of growth limitation measures (Kahn, 2005; Pendall, Martin, & Fulton, 2002; Portney, 2003). As Downs (2000) suggests, not understanding population growth limitation within the context of the region in which a city is located could make problems worse. In general, the research on the impact of growth management policies has focused on limited issues: land supply, land markets; housing densities, housing types, housing prices; the location, pattern, and pace of development (Dunphy, 1998; Miller & Hoel, 2002; Pendall, Martin, & Fulton, 2002). Studies on the relationship between cities' growth limitation measure and its impact on sustainability of the cities and their surrounding areas have not been sufficiently conducted (Portney, 2003). This study helps to understand such a relationship through a comparative analysis of municipalities in a metropolitan region.

Fourth, in order to get a better understanding of sustainability issues and solutions, there is a need to broaden current discussions about urban sustainability by including a variety of experiences. In the last decade, the studies have made the case for sustainability and documented progress toward it. As Sorensen, Marcotullio, and Grant (2004) point out, most of those works have focused on the European and North American experience. However, the usefulness of planning theories or policies varies from place to place. For instance, there has been a widespread belief that compact urban development, which has been advocated as a solution to urban sprawl, contributes to sustainability in the West (Breheny, 1996; Burton, Williams, & Jenks, 1996; De Roo & Miller, 2000; Masnavi, 2000; Miller & Hoel, 2002; Thorns, 2002). However, despite sharing many of the features of the compact city model (high density, mixed land uses, and high transit use, etc.), many Asian cities would not be seen as sustainable (Burgess, 2000; McGranahan, Songsore, & Kjellen, 1999). This study extends the literature on the compact city model by examining the pattern of sustainability in municipalities within the Seoul Metropolitan Region, Korea.

Fifth, there is a need for further research into means of assessing the aggregate effect of urban growth on sustainability. The technical aspects of urban sustainability assessment, such as assessment techniques and analytical procedures, are important for addressing sustainable urban development issues in a pragmatic fashion (Deakin, Mitchell, & Lombardi, 2002). There have been several approaches to measuring and assessing progress towards urban sustainability, including accounts, narrative assessments not based upon indicators, and indicator-based assessments (OECD, 2002b). Most of the urban sustainability indicator projects have mainly based upon indicator-based assessments. However, using indicator-based assessments in combination with statistical analysis methods can greatly help to provide a clear overall picture of the entire human and environmental conditions over time and to identity the factors affecting the process. Proper assessment and analysis techniques facilitate systematic comparison of cities, which leads to a more complete understanding of urban sustainability (Portney, 2003).

1.3 Research Objectives

The main purpose of this study is to measure and assess progress toward sustainable development at the local level based upon a set of indicators of sustainability, and to evaluate the impact of urban growth and change on sustainability based upon a comparative study of municipalities comprising Gyeonggi Province within the Seoul Metropolitan Region, Korea over the 1990-2000 period.

The specific objectives of this study are as follows:

(1) To identify the pattern of urban growth and change in the study areas and the

main factors affecting urban growth and change.

(2) To evaluate the existing indicators and adopt a set of sustainability indicators for the local level, and then to measure and assess progress toward sustainability in the study areas.

(3) To examine the impact of urban growth and change on urban sustainability and to identify the key elements affecting sustainability.

(4) To explore the policy and planning implications and challenges for sustainable development based upon the findings from (1) ~ (3).

1.4 Research Hypotheses

Five hypotheses related to the impact of urban growth and change on sustainability at the local level are examined. The research hypotheses are as follows:

(1) The level of urban sustainability tends to be higher in more densely populated areas than in less densely populated areas within a region.

(2) The trend of sustainability in urban areas with green belt tends to be stable over time, however, the trend of sustainability in their surrounding areas tends to decrease over time.

(3) The degree of sustainability of a region becomes greater over time.

(4) Different patterns of sustainability tend to emerge within different parts of a region. That is, the locational patterns of sustainability within a region tend to differ according to the patterns of growth and change in its sub-regions.

(5) Key factors affecting the pattern of sustainability within a region tend to change

over time.

1.5 Anticipated Contributions of the Research

By focusing on the sustainability effects associated with urban growth and change, this study will provide a better understanding of the prospects and problems of moving towards sustainability in rapidly growing urban areas in developing countries. It will contribute to an increased understanding of the causal relationship between urban growth and sustainable development by dealing with the sustainability impacts associated with urban growth and change. And, this study is also expected to contribute to providing valuable knowledge needed for urban planners and policymakers to meet the challenge of urban growth more effectively and to devise sustainable urban management strategies. The research findings are expected to add to the existing knowledge base in such a way that future development and growth in metropolitan regions in developing countries can be guided in a manner that enhances long-term sustainability.

1.6 Organization of the Dissertation

Chapter II reviews the literature regarding sustainable development. First, it looks into the historical background of sustainable development. It describes the concept of sustainable development and its intellectual traditions. This chapter also deals with sustainable urban growth and planning strategies. It also delves into previous studies of indicators of sustainable development. Finally, it introduces sustainability concerns in Korea.

Chapter III introduces the methodology used in this study. It begins with the selection of study areas. A set of urban sustainability indicators for measuring and assessing urban sustainability in the study areas is presented and the indicator relevance is discussed for each indicator. Data collection and data quality are also discussed. Finally, this chapter introduces the statistical methods for testing research hypotheses.

Chapter IV introduces growth management policies in the Seoul Metropolitan Region to understand the regional context of the study areas. It also describes the patterns of urban growth and change in the study areas over the 1990-2000 period.

Chapter V shows how research hypotheses were tested by statistical analyses and presents research findings.

Chapter VI provides summary and conclusions. It provides policy recommendations based upon major findings of this research. It discusses limitations of this research and also suggests directions for future research.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

This chapter consists of five sections. The first section reviews the historical background of sustainable development. The second section covers the concept of sustainable development and its intellectual traditions. The third section deals with sustainable urban growth and planning strategies. The fourth section reviews previous studies of sustainable development indicators. Finally, the fifth section introduces sustainable development concerns in Korea.

2.2 The Historical Background of Sustainable Development

2.2.1 The UN Conference on the Human Environment – 1972

Growing international concern about the impact of economic growth on the environment led to a call for an international conference on how to manage the human environment. The United Nations Conference on the Human Environment, held in Stockholm, Sweden in 1972, was the first major political meeting that was devoted to the environment (Dresner, 2002). The Conference called upon governments and peoples to make common efforts for the preservation and improvement of the human environment. The Conference adopted the Declaration of the United Nations Conference on the Human Environment, which contained 26 principles to inspire and guide the peoples of the world in the preservation and enhancement of the human environment. As a result of the Conference, the United Nations Environment Programme (UNEP), whose role is to promote international cooperation in the field of the environment, to recommend appropriate policies, and to bring emerging environmental issues to the attention of governments and the international community for action, was established in 1972 (Dresner, 2002).

In his book *Small is Beautiful*, which was released soon after the effects of the 1973 energy crisis shook the world, Schumacher linked concern about depletion of natural resources and pollution to development issues. Noting that the natural resources (especially fossil fuels) are not renewable and thus subject to eventual depletion and the capacity of nature to resist pollution is limited as well, Schumacher (1973) points out that our economy is unsustainable. Schumacher's work coincided with the growth of ecological concerns and with the birth of environmentalism.

2.2.2 The World Conservation Strategy – 1980

The World Conservation Strategy was produced in 1980 by the International Union for Conservation of Nature and Natural Resources (IUCN) in cooperation with the UNEP and the World Wildlife Fund. The main aim of the Strategy was to help achieve sustainable development through the conservation of living resources. It provided both an intellectual framework and practical guidance for the conservation actions. The Strategy identified the priority conservation issues and the main requirements for dealing with them and also proposed effective ways for achieving the Strategy’s aim. According to the Strategy, living resource conservation has three main objectives: (1) to maintain essential ecological processes and life-support systems; (2) to preserve genetic diversity; and (3) to ensure the sustainable utilization of species and ecosystems (IUCN, 1980).

The Strategy clarified the ideas of sustainable development. The Strategy says that ‘for if the object of development is to provide for social and economic welfare, the object of conservation is to ensure Earth’s capacity to sustain development and to support all life’ (IUCN, 1980). It also says that ‘for development to be sustainable, it must take account of social and ecological factors, as well as economic ones; of the living and non-living resource base; and of the long term as well as the short term advantages and disadvantages of alternative actions’ (IUCN, 1980).

2.2.3 Our Common Future – 1987

A growing perception that conventional approaches to economic development were failing contributed to an international movement to promote sustainable economic development (Hackett, 1998). The General Assembly of the United Nations created the World Commission on Environment and Development (WCED) in 1983 to look ahead at environment and economic development issues. The WCED, chaired by the then Prime Minister of Norway, Gro Harlem Brundtland, published its final report, *Our Common Future* (also called the Brundtland Report) in 1987. The report is viewed as a landmark document in terms of increasing the global awareness of sustainable development. It examines the world’s common concerns with a holistic perspective: population and human resources, food security, species and ecosystems, energy, industry, and the urban challenge of humans in their built environment. The report also makes institutional and legal recommendations for change in order to confront common global problems.

As mentioned earlier, the WCED provided the following definition of sustainable development in its report: ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’. While no single definition can claim universal agreement, this is the classic definition of sustainable development upon which nearly all other versions are based. The report offered an agenda advocating economic growth based on policies that do not harm the environment.

The following four principles of sustainable development are derived from the Brundtland Report and are the fundamental approaches to global sustainability (Newman & Kenworthy, 1999):

- The elimination of poverty, especially in the Third World, is necessary not just on human grounds but as an environmental issue.
- The First World must reduce its consumption of resources and production of wastes.
- Global cooperation on environmental issues is no longer a soft option.
- Change toward sustainability can occur only with community-based approaches that take local cultures seriously.

2.2.4 The Earth Summit – 1992

In 1992, more than 100 heads of state met in Rio de Janeiro, Brazil for the United Nations Conference on Environment and Development (also known as the Earth Summit) convened to address urgent problems of environmental protection and socio-economic development. The assembled leaders signed the Convention on Climate Change and the Convention on Biological Diversity. They endorsed the Rio Declaration on Environment and Development (also known as the Earth Charter), which contains 27 guiding principles for sustainable development. These principles include: the notions that people are at the center of concerns for sustainable development; the importance of integrating environmental concerns into the development process; international cooperation to help nations increase their carrying capacity; a recognition of the needs of future generations; the importance of indigenous people and local communities in environmental management and development; and participation in decision-making. They also agreed on an action plan for achieving sustainable development in the 21st century called ‘Agenda 21’. The Earth Summit was a significant milestone that set a new agenda for sustainable development.

Agenda 21 is a comprehensive global blueprint that outlines actions that governments, international organizations, industries and the community can take to achieve sustainable development. Agenda 21 addresses both environmental and developmental issues in an integrated manner at global, national and local levels. The key objective of Agenda 21 is the alleviation of poverty, hunger, and sickness worldwide while halting the degradation of ecosystems which sustain life. Agenda 21 consists of four sections:

(1) **Social and economic dimensions** - examines the underlying human factors and problems of development (poverty, consumption patterns, demographic dynamics, human health conditions, human settlement, etc.);

(2) **Conservation and management of resources for development** - the largest section of Agenda 21, presenting the range of resources, ecosystems and other issues (atmosphere, land, deforestation, desertification, agriculture, biological diversity, seas, water, solid wastes, sewage, etc.), all of which must be examined in detail if sustainable development is to be achieved at global, national and local levels;

(3) **Strengthening the role of major groups** - looks at the social partnerships necessary if sustainable development is to be achieved. It recognizes that nine major

groups (women, children and youth, indigenous people, non-governmental organizations, local authorities, workers and trade unions, business and industry, scientific and technological community, farmers) must be a key player in the development of policy and in achieving the necessary changes; and

(4) **Means of implementation** - looks at the various resources which must be mobilized in support of sustainable futures. While finance and technology are key elements, this section also deals with aspects of education, institutional and legal structures, data and information, and the building of national capacity.

Stating that many of the problems and solutions being addressed by Agenda 21 have their roots in local activities, Agenda 21 emphasizes that the participation and cooperation of local authorities is a determining factor in fulfilling its objectives. Chapter 28 of Agenda 21 calls upon all local authorities to consult with their citizens, local organizations and private enterprises and develop and implement a local Agenda 21, a program that provides a framework for implementing sustainable development at the local level. Local authorities play a key role in educating, mobilizing and responding to the public to achieve sustainable development.

The United Nations Commission on Sustainable Development (UNCSD) was created in 1992 to monitor and report on the implementation of the Earth Summit agreements at the local, national, regional, and international levels. At the 11^{th} session in 2003, the UNCSD agreed on its program of work beyond 2003 based upon the two-year cycles up until 2016/17. The first cycle was 2004/05, with the themes of water, sanitation and human settlements.

2.2.5 The World Summit on Sustainable Development – 2002

The World Summit on Sustainable Development (WSSD) took place in Johannesburg, South Africa in 2002 for a ten-year review of countries' Earth Summit progress. The WSSD dealt with all aspects of sustainable development, with the major focus on poverty and development. There was widespread concensus that environmental deterioration is a concomitant of poverty and thus cannot be satisfactorily addressed until poverty itself is addressed. The WSSD recognized that eradicating poverty is the greatest global challenge facing the world and an indispensable requirement for sustainable development.

The WSSD adopted the Johannesburg Declaration on Sustainable Development and the Johannesburg Plan of Implementation. Recognizing that sustainable development requires a long-term perspective and broad-based participation in policy formulation, decision-making and implementation at all levels, heads of state were committed to taking actions and measures to make sustainable development a reality in the Johannesburg Declaration. The required actions were spelled out in the Johannesburg Plan of Implementation.

2.3 The Concept of Sustainable Development

2.3.1 The Concept of Sustainable Development

The concept of sustainable development arose from the growing global realization that current economic development patterns could not be continued indefinitely due to environmental impacts. As previously stated, the most common definition of sustainable development is that used in the Brundtland Report. In essence, the concept of sustainable development contains three key dimensions: economic development, environmental protection, and social equity (Newman & Kenworthy, 1999; OECD, 2000; WCED, 1987). These three dimensions of sustainable development are interdependent and interlinked with each other. A key principle of sustainable development is the recognition of the interdependence of economic, environment and social concerns (OECD, 2000). These three dimensions involve complex synergies and trade-offs (Hediger, 2004; OECD, 2000). Therefore, to achieve sustainable development, all three dimensions need to be affected in harmony.

From the very definition of sustainable development, future generations are important stakeholders. Protecting their interests is fundamental to achieving sustainable development (OECD, 2002b). For intergenerational well-being, the concept of sustainable development highlights the need to balance the interests of current and future generations. It also implies limits – not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities (WCED, 1987). Sustainable development is not a state that is reached, but one toward which the world must constantly strive. As Newman and Kenworthy (1999) point out, it is a vision and a process, not an end product.

Following the Brundtland Report, there was an evolution of the economic/ecological debate into two competing approaches to the concept of sustainable development: weak sustainability and strong sustainability (Hackett, 1998). Both approaches are consistent with the definition of sustainable development the Report provides, but differ in how to achieve it. The weak sustainability approach is based upon the neoclassical theory of economic growth and capital accumulation in the context of limited resources, while the strong sustainability approach has developed from ecological economics (Anderson, 2004). In general, arguments in favor of limits to growth focus on the concept of strong sustainability, while arguments in favor of continued growth focus on the concept of weak sustainability (World Bank, 2003).

Weak sustainability implies that man-made capital can substitute for natural capital and the services provided by ecological systems (Anderson, 2004; George, 2000; Hackett, 1998; Hediger, 2004; Neumayer, 1999; OECD, 2002c; World Bank, 2003). The weak sustainability approach emphasizes the necessity of maintaining the value of the stock of total capital, man-made and natural (Hediger, 2004). As long as future generations obtain the stock of total capital not less than that of the present generation, the condition of sustainable development is satisfied even if this is done at the expense of drawing down the stock of natural capital (Hackett, 1998). Under this approach, there are no significant differences between different forms of capital and thus substitution of different forms of capital is allowed. However, the difficulty comes in ensuring that technically feasible substitutes for natural environmental benefits actually emerge in practice (OECD, 2002b). And, the weak sustainability approach does not take into account the fact that some natural capitals are not substitutable, and cannot be expressed in monetary terms.

In contrast, strong sustainability implies that natural capital cannot be duplicated or replaced (Anderson, 2004; George, 2000; Hackett, 1998; Hediger, 2004; Neumayer, 1999; OECD, 2002c; World Bank, 2003). The strong sustainability approach emphasizes the necessity of maintaining the stock of natural capital rather than total capital as a prerequisite of sustainable development (Hediger, 2004). This approach is based upon the idea that there are certain functions that the environment performs that cannot be duplicated by humans. This approach forbids trade-offs involving certain forms of critical natural capital (for example, national parks or other lands of high biodiversity value, wetlands and other ecosystems providing vital life-supporting functions) (Neumayer, 1999; OECD, 2002c). The strong sustainability approach argues that destruction of certain forms of natural capital is irreversible and thus manufactured or human capital cannot be substituted for natural capital. Under this approach, sustainable development occurs by conserving vital natural capital stocks that preserve ecological integrity (Anderson, 2004; Hackett, 1998). Denying the possibility of substitution implies that certain types of natural capital have absolute value, greater than any other consideration (OECD, 2002b). Thus, this approach is criticized for its failure to address the conflict that arises between economic, environmental, and social aspects of sustainable development (OECD, 2002b).

2.3.2 Intellectual Traditions of Sustainable Development

The accepted general meaning of sustainable development is a balance among economic, environmental, and social equity concerns. Sustainable development draws from five intellectual traditions: carrying capacity, fitness, resilience, diversity, and balance (Neuman, 2003).

Carrying capacity refers to the ability of natural and man-made systems to support the demands of various uses and inherent limits in the systems beyond which change cannot be absorbed without producing degradation or irreversible damage (Godschalk & Parker, 1995). The World Conservation Union (1991) defines sustainable development as 'improving the quality of human life while living within the carrying capacity of supportive ecosystems'. Carrying capacity persists as a mainstream definition of environmental planning for sustainable development (Beatley, 1995; Rees, 1996). The concept of carrying capacity became popular because it used factors that are easily measured and assessed. However, measuring capacity at a single point in time goes against the notion of sustainability as process (Neuman, 2003).

Fitness has a tradition in biology. Fitness implies an evolutionary process marked by the mutual interaction between species and environment (Neuman, 2003). Landscape architects and environmental planners endeavor to fit built structures and developments into natural landscapes without disrupting ecological systems irreparably (Ashby, 1978). Lynch (1981) measured people's perceptions about the quality of their environment in relation to the spatial, physical city and elucidated the connection between urban form and local culture.

Resilience is a process of adjustment through interaction, as is fitness (Ashby, 1978). However, instead of asking how well does an organism or activity fit into a given ecosystem or social community, resilience asks how well does a place absorb the presence of an organism or activity (Neuman, 2003). The modern city planning movement partly derives from the idea of resilience. In the late 19th century the urban expansion, tenement improvement, and civic hygiene movements in Europe and the United States diagnosed large cities as ill and not fit to live in (Neuman, 2003). Professionals proposed solutions to let in more light and air and to better treat wastes – that is, to make cities more resilient to the impacts produced by crowding (Hall, 1988).

Diversity refers to preserving biological diversity via environmental protection. Diversity also implies both the variety of members in a community and the positive disposition of members in relation to one another (Neuman, 2003). In urban planning it may take the form of multiple and mixed land uses instead of a single use. Likewise it is construed as promoting social diversity by inclusionary zoning that accommodates a range of incomes. Diversity has become a pervasive and persistent feature of sustainability debates (National Research Council, 1999).

Balance refers to balancing the natural environment with human development. The Brundtland Report (WCED, 1987) stressed a balance between development and environment, and between present and future generations.

These five intellectual traditions of sustainable development are not mutually exclusive. There are four commonalities among these traditions (Neuman, 2003). The first common feature of sustainable development is process. Sustainable development is an ongoing process of how to live (Newman & Kenworthy, 1999). A second commonality is health. To sustain an ecosystem or city over the long run assumes that it will be healthy (Neuman, 2003). A third common characteristic is place-specific conditions. For example, biodiversity refers to the number of different species in a particular habitat. A fourth feature of sustainable development is inter-relationships among system components, borrowing from systems theory and ecology.

These four commonalities (long-term process, health, place-specificity, and interrelationships) are closely connected to comprehensive city planning (Neuman, 2003). In this respect, sustainable development inherently encompasses the planning of cities, and provides a solid foundation for professions concerned with cities (Berke, 2000; Campbell, 1996).

2.4 Sustainable Urban Growth and Planning Strategies

2.4.1 Sustainability Goals for Cities

As mentioned above, sustainable development is seen as a tool to balancing economic development, social equity, and environmental protection for current and future generations. The concept and principles of sustainable development can be applied to cities in that sustainable development is strongly linked to socio-economic and environmental aspects of cities.

Based upon the Extended Metabolism Model of Human Settlements, which focuses on resource inputs and waste outputs from cities, Newman and Kenworthy (1999) define the goal of sustainability in a city as the reduction of the city's use of natural resources (land, energy, water, building material, etc.) and production of wastes (solid waste, sewage, air pollutants, etc.), while simultaneously improving its livability (health, employment, housing, education, accessibility, community, etc.), so that it can better fit within the capacities of local, regional, and global ecosystems. The Santa Monica Sustainable City Plan, adopted in 2003, includes goals for the city government and all sectors of the community, to conserve local resources, safeguard human health and the environment, maintain a diverse economy, and improve the livability and quality of life for all community members in Santa Monica. The Sustainable City Plan includes eight goal areas that present a vision for sustainability in the community. The specific goals addressed in the Plan are as follows (City of Santa Monica, 2005a):

(1) Resource Conservation

· Significantly decrease the consumption of non-local, non-renewable, non-recyclable and non-recycled materials, water, and energy and fuels.

· Within renewable limits, encourage the use of local, non-polluting, renewable and recycled resources (water, energy–wind, solar and geothermal– and material resources).

(2) Environmental and Public Health

· Protect and enhance environmental health and public health by minimizing and where possible eliminating:

- The use of hazardous or toxic materials by residents, businesses and city operations;
- The levels of pollutants entering the air, soil and water; and
- The risks that environmental problems pose to human and ecological health.

· Ensure that no one geographic or socioeconomic group in the city is being unfairly impacted by environmental pollution.

· Increase consumption of fresh, locally produced, organic produce to promote public health and to minimize resource consumption and negative environmental impacts.

(3) Transportation

· Create a multi-modal transportation system that minimizes and, where possible, eliminates pollution and motor vehicle congestion while ensuring safe mobility and access for all without compromising our ability to protect public health and safety.

· Facilitate a reduction in automobile dependency in favor of affordable alternative, sustainable modes of travel.

(4) Economic Development

· Nurture a diverse, stable, local economy that supports basic needs of all segments of the community.

· Businesses, organizations and local government agencies continue to increase the efficiency of their use of resources through the adoption of sustainable business practices.

(5) Open Space and Land Use

· Develop and maintain a sufficient open space system so that it is diverse in uses and opportunities and includes natural function/wildlife habitat as well as passive and active recreation with an equitable distribution of parks, trees and pathways throughout the community.

· Implement land use and transportation planning and policies to create compact, mixed-use projects, forming urban villages designed to maximize affordable housing and encourage walking, bicycling and the use of existing and future public transit systems.

· Residents recognize that they share the local ecosystem with other living things that warrant respect and responsible stewardship.

(6) Housing

· Achieve and maintain a mix of affordable, livable and green housing types throughout the city for people of all socio-economic/cultural/household groups.

(7) Community Education and Civic Participation

· Community members of all ages participate actively and effectively in civic affairs and community improvement efforts.

· Community members of all ages understand the basic principles of sustainability and use them to guide their decisions and actions - both personal and collective.

(8) Human Dignity

· All its members are able to meet their basic needs and are empowered to enhance the quality of their lives.

· There is access among community members to housing, health services, education, economic opportunity, and cultural and recreational resources.

· There is respect for and appreciation of the value added to the community by differences among its members in race, religion, gender, age, economic status, sexual orientation, disabilities, immigration status and other special needs.

In sum, sustainability goals for cities are derived based upon three components of sustainable development: economic development, environmental protection and social equity. The goals of sustainability can sometimes be conflicting. For instance, applying fertilizer might help enhance agricultural productivity but cause adverse effects on groundwater. In this respect, for cities to achieve sustainable development, it is important to obtain a balance between conflicting goals.

2.4.2 Urban Sprawl and Growth Management

Urban sprawl represents the dominant mode of growth in many metropolitan areas (Carruthers, 2002). Urban sprawl results from the interaction between pulling factors and pushing factors: cheap open land outside the city, advances in transportation, automobile ownership, easily available capital to buy property, mass production of housing, the desire for the single family home, and overcrowding in dense urban areas (Nelson & Duncan, 1995; Neuman, 2003; Young, 1995). Many of the studies on urban sprawl conclude that overall, urban sprawl is more costly than compact development, for both operating and capital costs (Burchell et al., 2002).

Burchell et al. (1998) defined urban sprawl in the United States as a form of urban development that contains most of the following ten elements: (1) low residential density, (2) unlimited outward extension of new development, (3) spatial segregation of different types of land uses through zoning, (4) leapfrog development, (5) no centralized ownership of land, or planning of land development, (6) all transportation dominated by privately owned motor vehicles, (7) fragmentation of governance authority of land uses among many local governments, (8) great variances in the fiscal capacity of local governments, (9) widespread commercial strip development along major roadways, and (10) major reliance on a filtering process to provide housing for low-income households.

Urban sprawl has a number of negative consequences and thus has been extensively criticized for being inefficient, inequitable and environmentally insensitive (Carruthers, 2002). It contributes to excessive commuting and transport costs, raising the cost of providing infrastructure, promoting socioeconomic segregation through housing markets, and increasing the consumption of natural resources, including forests, farmlands, open space and wildlife habitats (Brueckner, 2000; Carruthers & Ulfarsson, 2002; Smart Growth BC, 2001).

Many growth management techniques have been developed as a response to the problems and processes associated with urban sprawl (Nelson & Duncan, 1995). Growth management seeks to direct growth in a manner consistent with defined policy objectives for sustainable and balanced growth. Growth management approaches include various options: urban containment techniques; zoning; housing/population caps; infrastructure adequacy requirements, etc. In particular, as policymakers perceive that other land-use planning policies have failed to control urban sprawl, they have become increasingly interested in urban containment tools (Pendall, Martin, & Fulton, 2002).

Urban containment policy represents an attempt to control the spatial pattern of development within a community or region by creating geographical constraints on urban growth (Nelson & Duncan, 1995; Pendall, Martin, & Fulton, 2002). Specific urban containment tools include greenbelts, urban growth boundaries and urban service areas.

Greenbelts are tight bands of green space around an existing urban area.

Greenbelt policies have been extensively implemented in Korea and the United Kingdom (Flint & Flint, 2001; Kim & Kim, 2000). In the United States, only a few communities have conscious greenbelt policies. The most prominent case is Boulder, Colorado, which has used both regulation and public acquisition to establish and maintain the greenbelt around the city. In 1967, Boulder became the first city in the United States to impose a tax on residents for the acquisition and preservation of open space for a greenbelt around the city (Pendall, Martin, & Fulton, 2002). Boulder has purchased open space within city limits and in adjacent counties. It is said that the greenbelt has helped preserve parks and open space in Boulder as the city has grown.

Urban growth boundaries are defined as a set of land-use regulations that prohibits urban growth and development outside a certain boundary (Pendall, Martin, & Fulton, 2002). While greenbelts constrain the geographical expansion of urban areas mainly through public ownership of undeveloped land, urban growth boundaries seek to achieve the same goal through the use of regulatory techniques, such as zoning (Pendall, Martin, & Fulton, 2002).

The best-known effort to control the pattern of urban growth is Portland, Oregon's urban growth boundary, which restricts development to within the boundary and protects land outside the boundary. Portland has the reputation of being the municipal pioneer of sustainable development (Richardson & Gordon, 2001). Oregon implemented its strong statewide program for land use planning in 1973. The Oregon Land Conservation and Development Act of 1973 is seen as the strongest state growth management law in the United States (Pendall, Martin, & Fulton, 2002). It requires each city and county to have a comprehensive plan and attendant ordinances, which are consistent with the statewide planning goals. The Act also requires the drawing of urban growth boundaries around all the state's cities and a metropolitan growth boundary around the Portland region. Thus, cities in Oregon are able to decide how and where growth will take place when they designate their urban growth boundaries. Portland Metro, a metropolitan planning authority, established the Portland regional urban growth boundary in 1979.

Urban service areas are geographically defined boundaries that specify where the local government will provide public infrastructure services, such as water lines, sewer lines, or streets, in the future. Urban service areas are more flexible in expansion because they are drawn mostly consistent with the economics of planned public facilities (Nelson & Duncan, 1995). Various municipalities use urban service areas. In 1976, San Jose, California established the San Jose Urban Service Boundary, a line beyond which public infrastructure would not be extended. The urban service boundary aimed to slow the rate of rural land conversion by encouraging higher density infill development within the boundary. In Minneapolis-St. Paul, Minnesota, the Metropolitan Council established the Metropolitan Urban Service Area in 1975. The urban service area boundary is drawn based on a calculation of the 10-year capacity to support new growth and is reconsidered every five years. As in other cities, maintenance of the urban service area boundary is supplemented by regulatory controls that encourage infill development within the boundary and discourage new development outside it. Orange County, Florida adopted an Urban Service Area as part of its 1980 Comprehensive Plan. The Urban Service Area was designated for providing public services for an area to accommodate anticipated growth over the next 15 years.

There are the amenities and efficiencies of growth management policy. However, some researchers have found that there are negative side effects of growth management policy. One of contentious issues is the effect of urban growth boundary on the availability of affordable housing (Miller & Hoel, 2002). Based upon a study of Portland's housing prices, Dunphy (1998) contends that the urban growth boundary has a significant impact on land prices. In a study of the effect of growth management policy on housing markets, Pozdena (2002) argues that the site-supply restrictions are bound to raise home prices and the burden of site-supply restrictions will fall disproportionately on poor and minority families. In Boulder, urban containment policies stimulated leapfrogging into suburban communities beyond the greenbelt (Pendall et al., 2002). These results indicate that the challenge is to balance the problem addressed by growth management policy and its negative impacts (Dunphy, 1998; Pozdena, 2002).

The studies on the impact of growth management policies have focused mainly on limited issues: land supply, land markets; housing densities, housing types, housing prices; the location, pattern, and pace of development (Dunphy, 1998; Miller & Hoel, 2002; Pendall, Martin, & Fulton, 2002). However, not understanding the effect of growth limitation measures within the context of the region in which a city is located could make problems worse in that cities within metropolitan regions interact closely (Downs, 2000). In this respect, empirical studies of the relationship between a city's growth limitation measure and its impact on sustainability of the city and surrounding areas are needed to assess whether such a measure encourages the pursuit of sustainability (Portney, 2003).

2.4.3 Smart Growth

The important planning movement to cope with urban sprawl is the idea of smart growth, which tries to overcome the problems caused by sprawl by taking sustainable approaches to urban growth and development (Benfield, Terris, & Vorsanger, 2001; Foster, 2000; Miller & Hoel, 2002; O'Connell, 2003; Smart Growth BC, 2001). Smart growth is a planning approach that concentrates development into existing urban areas, resulting in high-density, mixed-use development, with a variety of transportation choices (Cox & Utt, 2001; Holcombe & Staley, 2001; Miller & Hoel, 2002; O'Connell, 2003; Shaw & Utt, 2000). The idea of smart growth underlines urban consolidation rather than wasteful and expensive leapfrog suburban sprawl (Palen, 2002; Thorns, 2002).

There is no single definition of smart growth and its meaning depends on context and perspective. National Association of Counties et al. (2001) define smart growth as 'a series of strategies and initiatives designed to help communities plan for and accommodate growth in ways that help secure their economic prosperity and environmental safety, while preserving the unique aspects of their communities'. Smart Growth BC (2001) defines it as 'land use and development practices that enhance the quality of life in communities, preserve the national environment, and save money over time'. In sum, smart growth seeks development that serves the economy, the community, and the environment.

The Smart Growth Network, a network of private sector, public sector, and non-governmental organizations seeking to create smart growth in neighborhoods, communities, and regions across the United States, was formed in 1996 in response to increasing concerns about the need for new ways to grow that boost the economy, protect the environment, and enhance community vitality. The Smart Growth Network promotes strategies to minimize development's negative impacts on the economic, social and environmental aspects of a community.

The Smart Growth Network has developed the following ten basic principles as a framework for smart growth action that can be applied in various combinations to create smart, non-sprawling communities:

- mix land uses
- take advantage of compact building design
- create a range of housing opportunities and choices
- create walkable communities
- foster distinctive, attractive communities with a strong sense of place
- preserve open space, farmland, natural beauty, and critical environmental areas
- strengthen and direct development toward existing communities
- provide a variety of transportation choices
- make development decisions predictable, fair, and cost-effective
- encourage community and stakeholder collaboration in development decisions

In 2003, the Smart Growth Network and the International City/County Management Association published *Getting to Smart Growth II*, which describes concrete techniques for putting smart growth principles into practice. This publication provides policy options to achieve each of the above 10 smart growth principles. For instance, to achieve the principle of ‘mix land uses’, the document presents the following ten policies (Smart Growth Network & International City/County Management Association, 2003):

- adopt comprehensive plans and sub-area plans that encourage a mix of land uses
- use enhanced zoning techniques to achieve a mix of land uses

- provide regional planning grants for projects that produce mixed land use
- encourage the redevelopment of single uses into mixed-use developments
- accommodate the reuse of closed, decommissioned, or obsolete institutional uses
- provide incentives for ground-floor retail and upper-level residential uses in existing and future development
- locate neighborhood stores in residential areas
- use floating zones to plan for certain types of undetermined uses
- organize a variety of land uses vertically and horizontally
- develop mixed-use university districts

Smart Growth BC, a non-profit society devoted to creating more livable communities in British Columbia, Canada, published *the Smart Growth Toolkit* in 2001, which highlights important local government functions, such as land-use planning, development regulations, and the major policy development processes that support smart growth objectives. Smart Growth BC (2001) provides the specific smart growth tools based on five categories: growth management strategies; land use planning & urban design; economic incentives; demand management practices; and ecosystem planning.

Efforts have been made to promote smart growth practices through the comprehensive use of alternative development strategies. Maryland's Smart Growth initiatives, which include a set of state laws and programs passed by the Maryland legislature beginning in 1997, are recognized as an innovative approach to directing new growth and to revitalizing older, developed areas (Cohen, 2002). The five core programs of Maryland Smart Growth are: (1) the 1997 Smart Growth Areas Act, which directs state funding into already developed areas and areas planned for growth; (2) the 1997 Rural Legacy Act, which provides funds to local governments and land trusts to purchase land, easements and transferable development rights in designated rural legacy areas; (3) the Brownfields Voluntary Cleanup and Revitalization Incentive Programs, which stimulate the reuse of contaminated, vacant/underused industrial sites; (4) the Job Creation Tax Credit Program, which encourages businesses to expand or relocate in Maryland by providing tax credits for new jobs; and (5) the Live Near Your Work Program, which creates incentives for workers to buy homes near their workplaces (Cohen, 2002). Maryland’s Smart Growth initiatives are characterized by using incentives to combat sprawl and to support existing communities.

Austin, Texas, also encourages smart growth in a variety of ways. The Smart Growth Initiative is the City of Austin's plan to preserve and enhance the livability of Austin by guiding and shaping growth. The Smart Growth Initiative includes a number of related policies and programs such as neighborhood planning, infill & redevelopment amendments, downtown redevelopment program, and open space preservation (City of Austin, 2005).

As Smart Growth BC (2001) states, promoting smart growth is not about fighting against growth and development, but about enhancing the quality of life in communities by presenting strategies that are sustainable and responsible. A wide range of smart growth strategies is available to create more livable communities. However, each community has its own unique challenges and opportunities, and thus the approach to smart growth demands a flexible response (Smart Growth Network & International City/County Management Association, 2003). Therefore, the usefulness of specific smart growth options depends on local circumstances.

2.4.4 Urban Form and Sustainability

It has been argued that there are strong relationships between urban form and sustainable development (Beatley, 1995; Newman & Kenworthy, 1999). Dispersed urban development has led to environmental deterioration, increased energy consumption for transportation, and pollution (Masnavi, 2000). The idea of the compact city has been advocated as a solution (Burton, Williams, & Jenks, 1996). It is perceived that the intensity of activities, such as traffic and industry, is one of major factors affecting sustainability (De Roo & Miller, 2000). In general, the compact city policy has been a response to the outward movement of growth called urban sprawl (De Roo & Miller, 2000).

Attempts to halt sprawl and improve urban livability have been made by compact city, smart growth, and new urbanist advocates (Miller & Hoel, 2002; Thorns, 2002). The classic response to urban sprawl has been compact urban development. The compact city has been seen as a counter strategy for reducing the spread of low density urban development and preserving the countryside (De Roo & Miller, 2000). Low density development, which is associated with decentralization, can lead to increased automobile travel and fuel consumption, and reduced effectiveness of public transportation (De Roo & Miller, 2000; Newman & Kenworthy, 1992). Consequently, it is reasoned that higher densities and mixed uses reduce trips lengths and make public transport an attractive option. Thus, it is said that the compact city is more energy efficient and less polluting because compact city dwellers can live closer to shops and work, and can walk, bike, or take transit (Neuman, 2003).

Whereas decentralization tends to be advocated by theorists from the U.S. and

Australia, the compact city can be seen as the vision of European cities (Jenks, Burton, & Williams, 1996; Sorensen, Marcotullio, & Grant, 2004). In the United States, compact cities are also called transit-oriented developments and are promoted through the smart growth movement (Neuman, 2003). Main characteristics of the compact city include the following fifteen elements: (1) high residential and employment densities, (2) contained growth, demarcated by legible limits, (3) mixed land uses, (4) fine grain of land uses, (5) contiguous development (some parcels or structures may be vacant or abandoned, or surface parking), (6) multi-modal transportation, (7) urban infrastructure, especially sewerage and water mains, (8) high degrees of accessibility, (9) sidewalks, curbs, bicycle lanes, (10) high degree of impervious surface coverage, (11) high open space ratio, (12) population diversity, (13) increased social interaction, (14) unitary control of planning of land development, or closely coordinated control, and (15) sufficient government fiscal capacity to finance urban facilities and infrastructure (Burton, 2000; Neuman, 2003).

Are compact cities more sustainable than non-compact cites? Is compact urban form the best planning strategy to attain a more sustainable city? It is said that a compact city is more sustainable (Beatley, 1995; Jenks & Burgess, 2000; National Research Council, 1999; Newman & Kenworthy, 1999, 2000; United Nations, 1992). Compact forms confer advantages such as lower land consumption, cheaper infrastructure and utility costs, low emissions, reduced energy consumption, increased accessibility, and the preservation of green space (Beatley, 2000; Burchell et al., 2002; Hillman, 1996; Thomas & Cousins, 1996). In particular, the relationship between compactness and travel patterns is central to the sustainable urban form debate (Williams, Burton, & Jenks, 2000). In their investigation of the relationship between density and car dependence in cities worldwide, Newman and Kenworthy (2000) found that density is a major explanatory variable for the level of automobile use, and then concluded that achieving a more sustainable urban form involves the development of densities that can enable public transport, walking and cycling to be viable options.

However, development at higher densities may also result in unsustainable externalities and impacts in those higher density areas such as air pollution, traffic congestion, loss of amenity space, loss of vacant green areas within cities, and reduction of privacy (Burton, Williams, & Jenks, 1996; De Roo & Miller, 2000; Knight, 1996; White, 2002). Increased density does not necessarily result in reduced car dependency and reduced trip making (De Roo & Miller, 2000). Empirical studies by Breheny (2001) and Williams, Burton, and Jenks (2000) are not conclusive about the relationship between higher densities and reduced automobile trips. Growth in car ownership, weekend air travel, business travel, and dispersed life patterns have led to the inability of physical design alone to reduce travel demands of energy-rich transport modes (Williams, Burton, & Jenks, 2000). Travel may be much more strongly linked to fuel prices and income than population density (Hall, 2001). Compact settlements with an emphasis on density and public transportation only address a few of the ills attending modern metropolises (Neuman, 2003). Outlining eleven reasons why low-density development is desirable, Gordon and Richardson (1997) challenge planning wisdom that encourages higher-density, compact cities as a substitute for lower-density suburban development.

Cities are complex systems. Urban sustainability is a multi-dimensional phenomenon. There is a need to recognize the complex set of relationships affecting sustainability (De Roo & Miller, 2000). In this respect, the approach focusing on a single aspect (for example, energy efficiency and urban form) is not likely to generate a reliable basis for the generation of concepts of a sustainable city (Frey, 1999). Any improvement of one aspect of the city needs to be weighed against other benefits or losses (Frey, 1999). For instance, deficiencies of the compact city such as a lack of greenery, open spaces and parks, and a lack of privacy must be addressed if the compact city is to compete with the attractiveness of low-density areas (Masnavi, 2000). The compact city fallacy contends that the compact city is neither a necessary or sufficient condition for a city to be sustainable, and that the attempt to make cities more sustainable only by using urban form strategies is counterproductive (Neuman, 2003). As Burton, Williams, and Jenks (1996) point out, in order to assess urban sustainability, the city needs to be seen as a whole and all aspects must be taken into account. Moreover, despite sharing many of the features of the compact city model (high density, mixed land uses, and high transit use, etc.), many Asian cities would not be seen as sustainable (Burgess, 2000; McGranahan, Songsore, & Kjellen, 1999). In this respect, there is a need to extend the literature on the compact city model through an empirical analysis of a variety of experiences in cities with different development and growth patterns in developed and developing countries.

2.4.5 Planning Practices Toward Urban Sustainability

According to traditional conceptions of growth and development in cities, the city is seen as a growth machine and growth is seen as the engine that drives the health of the city (Portney, 2003). However, recent conceptions of growth and development express concern about unmanaged or improperly managed development and its negative consequences such as urban sprawl, deteriorating inner-city infrastructure, traffic congestion, the waste of natural and human resources, and so on (Portney, 2003).

In particular, rapid urban growth causes a number of urban problems, such as inadequate housing and urban services (water, sanitation, transport, etc.), spiraling land prices, and deterioration of the urban environment. Under this circumstance, the main challenge facing local governments is to ensure sustainability of urban growth and development. As mentioned above, sustainability goals for cities are comprehensive and planning tools for achieving sustainability are diverse. Cities make attempts to achieve sustainability goals through various policies and programs. There have been a number of local efforts to facilitate and encourage movement toward creating more sustainable communities.

Land Use

An increasing number of local governments are encouraging mixed land uses, more compact development patterns, and preservation of farmland and open space (National Association of Counties et al., 2001). Mixed uses contribute to reducing auto dependence, increasing demand for transit, and generating social and economic diversity (Grant, 2004). Mixed uses are central to the principles of smart growth and transit-oriented developments. As mentioned earlier, mixing land uses is one of key principles of smart growth developed by the Smart Growth Network. Transit-oriented developments mix residential, commercial, office, open space, and public uses in a walkable environment around a transit stop (Calthorpe, 1993). Mixed uses promote compact development that is more pedestrian-friendly and easier to service with public transportation. In the City of Virginia Beach, Virginia, in order to accomplish the transition from 'less intense to more intense land use' within the Strategic Growth Areas identified by the latest Comprehensive Plan, the Plan suggests developing mixed use as a preferred land use pattern, and developing necessary zoning and other regulatory tools to encourage it (City of Virginia Beach, 2004). Atlantic Station, Atlanta, Georgia, is cited as a compact, mixed-use development built on an abandoned industrial site in central Atlanta (Benfield, Terris, & Vorsanger, 2001).

Some local governments adopt a Transferable Development Rights (TDRs) program as a market approach to preserving farmland, open space and historic sites. TDRs are building rights that can be transferred from one property to another. Generally, TDRs are transferred from a less desirable area for development to one where higher density is desirable (National Association of Counties et al., 2001). Montgomery County, Maryland, has been the most successful program, having preserved over 40,000 acres of farmland and open space since the adoption of the program in 1980. Boulder County, Colorado, adopted the program in 1995.

In growing cities, it is important to control the rate of growth. The City of Petaluma, California, limits residential construction in the city to a maximum average of 500 allotments per year (City of Petaluma, 2002). This system exempts multifamily housing for the elderly and low-income households. In Sonoma, California, the Growth Management Ordinance limits residential development within the city to an average of 100 units per year, a level determined to allow for manageable increases in service and infrastructure demand without placing undue burden on existing services or other infrastructure (City of Sonoma, 2004). Boulder, Colorado, also adopts a residential growth limit policy. In 1995, the City Council reduced the annual number of residential permits allowed from two to one percent of the existing residential base. Small projects on existing lots are exempted from the dwelling unit limits.

Transportation

Transportation has enormous effects on housing, employment, environment and social equity (National Association of Counties et al., 2001). Achieving sustainable urban accessibility is important for improving the urban environment and maintaining the economic viability of cities. To achieve sustainable urban transport, viable alternatives to driving need to be provided through promoting a variety of transportation choices, including mass transit, biking, and walking (Smart Growth Network & International City/County Management Association, 2003; Stead, 2000).

Using the Intermodal Surface Transportation Efficiency Act funds, Boulder has established an efficient, environmentally sound small-bus shuttle service (National Association of Counties et al., 2001). The service has improved access in and around the congested core and also contributed to reducing drive-alone trips. A community group including business owners, university students and staff, employment center representatives, and residents, participated in establishing the shuttle’s route, stops, frequency, and fares.

Glendale, California, focuses on reducing traffic congestion and air pollution through parking management and carpool incentive packages. A public-private partnership between the Glendale Transportation Management Association, Nestle USA, Inc., and Commonwealth Land Trust Company, initiated a three-year program, which used incentives to encourage employees to use alternative commuting options such as carpools, vanpools, bicycling, walking, and transit, and eliminated parking subsidies for employees who drove alone (National Association of Counties et al., 2001). As a result, there was an increase in average vehicle occupancy from 1.15 to 1.5 persons per vehicle and there was a 30 percent reduction in solo driving at Nestle and a 25 percent reduction at Commonwealth Land Trust (National Association of Counties et al., 2001).

Davis, California, has been recognized as a model for bicycling because of the city's high rate of bicycle use (20-25% of all trips being taken by bicycle) and its long history of providing a cyclist-friendly environment (City of Davis, 2001). Since the Davis City Council made a conscious effort to promote bicycle use in 1966, the city’s bikeway system has steadily expanded. As a result of actively planning for bicycle use, the city, with an area over ten square miles, has about 48 miles of bike lanes and 49 miles of bike paths. More than 80 percent of all collector and arterial streets have bike lanes and/or bike paths.

Housing and Building

Affordable Housing. An important part of any urban sustainability strategy is to ensure that a range of housing options is available for a variety of income levels. Montgomery County, Maryland, uses an inclusionary zoning program to increase the provision of affordable housing. Under this zoning program, between 12.5 and 15 percent of the total number of units in a residential development of 50 or more units must be affordable for lower-income households (State of Minnesota, 2001). To partially offset the cost of building affordable housing, the county increases the development's density.

Austin, Texas, created a housing policy initiative called SMART (safe, mixed income, accessible, reasonably-priced, and transit-oriented), which requires that a certain number of housing units be affordable for families with no more than 80 percent of median family income (Smart Growth Network & International City/County Management Association, 2003). These housing units must be located one-quarter mile or less from transit. In addition, cities provide a number of incentives to increase the supply of affordable housing, including impact fee exemptions, dedicated funding, public land provision, and relief from regulations.

Green Building. A green building, also known as a sustainable building, is a structure that is designed, built, or operated in an environmental and resource-efficient manner. Green buildings contribute to protecting occupant health, using energy, water, and other resources more efficiently, and reducing the overall impact on the environment. Boulder, Colorado, operates the Green Points Building Program to encourage cost-effective and sustainable residential building methods, conservation of natural resources, recycling of construction materials, reducing solid waste and improved indoor air quality (City of Boulder, 2004). The program aims to create incentives for inclusion of green building practices into the construction of homes. The Green Points Program applies to all new residential construction, additions and remodels larger than 500 square feet. This program requires applicants to earn "green points" by selecting green building measures in order to receive a building permit.

Portland, Oregon, also operates a Green Building Initiative for environmentally friendly building development. In 2002, Portland became the first city in the United States to gain approval from the U.S. Green Building Council, which developed LEED (the Leadership in Energy and Environmental Design rating system), to implement its own green building rating system called “Portland LEED” (Magnusson, 2005). This program provides a well-established set of standards for what constitutes a green building.

Economic Development

The type and composition of a local economy can play a critical role in achieving urban sustainability goals (Beatley, 2000). Local economic policies have a significant effect on various aspects of cities, including land use, transportation, environment, health, social equity and education (National Association of Counties et al., 2001). Increasingly, global forces also influence the local economy. Therefore, municipalities need an integrated approach to local economic policies.

In response to a declining manufacturing base and urban decay during the mid-1970s and 1980s, the City of Chattanooga, Tennessee, undertook multiple revitalization projects in order to enhance the downtown area’s economic status and reverse its reputation as the ‘worst-polluted city’ in the United States (Georgia Institute of Technology, 1999). The projects covered a variety of fields, including electric shuttle service, affordable housing, and waste reduction, contributing to moving the city from a deteriorating, environmentally troubled downtown to a community poised for growth (Georgia Institute of Technology, 1999).

Brownfield redevelopment has been increasingly important to abandoned industrial or commercial properties that pose economic and environmental threats (Georgia Institute of Technology, 1999; National Association of Counties, 2001; White, 2002). In Kalamazoo, Michigan, a large inventory of abandoned, contaminated industrial and commercial properties weakened the city's tax base and limited the city's economic development efforts. The city's Brownfield Redevelopment Initiative, begun in 1994, was one of the first USEPA Brownfields Pilot Programs. This initiative stimulated investment in economically distressed neighborhoods and helped to revitalize the city's urban core (Georgia Institute of Technology, 1999).

Durham, North Carolina, transformed an old tobacco plant into a center that houses an incubator and training and social services facility (called the Golden Belt Business Education Service Center), which contributed to revitalizing an abandoned manufacturing facility, stimulating business growth, and providing affordable office space (Georgia Institute of Technology, 1999).

Environment

Air Quality. Boulder operates the Air Quality Program to reduce air pollution emissions. As the result of a voluntary reporting program initiated in 1996, manufacturing firms have developed pollution prevention plans and goals, and provide the city with reports on their efforts to reduce pollution (Portney, 2003). In 1993, Portland became the first local government in the U.S. to adopt a plan to address global warming. The city put into place a greenhouse gas reduction strategy in 1993 that called for the reduction of the city's carbon dioxide emissions by 20% from 1990 to 2010 (Portney, 2003).

Waste Management. Local governments have created various methods for the management of municipal solid waste. In particular, the Pay-As-You-Throw (PAYT) system has been adopted by many communities to reduce waste and conserve natural resources. Under this system, residents are asked to pay for each container of waste they generate. After implementing PAYT, communities report reductions in waste amounts of 25-35 percent, including significant increases in recycling rate (USEPA, 1997).

To achieve the goal of recycling 50% of the city's waste by 2005, Boulder implemented PAYT to the residential trash customers in 2001. This system has helped increase the recycling rate (49%) for residential sector. To encourage participation in business recycling, the city assists the commercial sector to recycle by offering a financial incentive to start a recycling program. In other communities, PAYT has also had an enormous impact on residential waste recycling rates. San Jose saw its residential recycling rate increase from 28% to 43% in the first year of its PAYT program. Seattle has increased its recycling rate from 19% to 49% through PAYT.

Energy. Traditional, nonrenewable energy sources such as oil and coal harm the environment in their extraction, processing, and use. They cause air, water, and soil pollution and contribute to global warming. Instead, renewable energy, which comes from the sun, wind, water, the burning of organic matter, and the heat of the Earth, is sustainable. Austin stands out for its commitment to renewable energy, with the aggressive goal: 20

percent of energy needs to be met by renewable energy and energy efficiency by 2020 (Magnusson, 2005). Austin's Renewable Energy Program, called GreenChoice, has helped promote renewable energy use in the city. Chicago has agreed to purchase 20 percent of its electricity from renewable energy sources by 2006 (Magnusson, 2005). The city offers tax incentives to residents who install energy efficient technologies.

Green Businesses. Portland operates the BEST program (Businesses for an Environmentally Sustainable Tomorrow) in order to encourage and assist local businesses in becoming more energy- and resource- efficient, and less environmentally polluting (Beatley, 2000). Each year the program announces its BEST Business Awards which are presented to businesses with significant achievements in the following categories: energy efficiency, water conservation, stormwater management, waste reduction/pollution prevention, transportation alternatives, sustainable food systems development, and sustainable product development.

Boulder’s PACE (Partners for a Clean Environment) program is a voluntary, non-regulatory program that offers pollution prevention education and technical assistance to Boulder County businesses. PACE is a partnership of local governments and businesses to help Boulder County businesses reduce waste and prevent pollution. The program assists and certifies the following sectors in pollution prevention and waste reduction: dental offices, manufacturers, auto repair shops, restaurants, landscape professionals, fleets, printers and auto body shops.

2.4.6 Conclusion

Urban growth and change has a significant effect on various dimensions of cities, including land use, transportation, environment, economic growth, and housing (Brueckner, 2000; Carruthers & Ulfarsson, 2002; Kahn, 2005; Smart Growth BC, 2001). And, urban growth and change has both positive and negative consequences for cities in various fields. Therefore, in order to better understand the impact of urban growth and change, there is a need for an integrated approach to the impact of urban growth and change. Urban sustainability deals with economic, environmental and social aspects of cities in a balanced, holistic way (Campbell, 1996; Fung & Kennedy, 2005; Maclaren, 1996). In this respect, a study of the impact of urban growth and change on urban sustainability offers an analysis framework for dealing with the impact of urban growth and change in a holistic, integrated manner.

Cities continue to change. A wide variety of socio-economic factors get involved in the process of growth and change of cities. Achieving urban sustainability is the key to cities' future. As Portney (2003) states, cities that pursue sustainability need to manage growth and development to be more consistent with their visions of what kind of community they desire to achieve. In general, the patterns of urban growth have an enormous effect on determining urban sustainability (Kahn, 2005). That is, different patterns of urban growth are expected to generate different impacts.

In a situation of rapid urban growth and change in developing countries in particular, there is an increasing need for an empirical investigation that traces the impact of urban change on sustainability through time by comparing cities, in order to provide valuable information needed for sustainable urban management (Drakakis-Smith, 1996). And, more attention needs to be paid to the patterns and processes of urban growth and change in order to avoid negative, unintended consequences of rapid urbanization (Redman, 2005). In this respect, there is a need for an increased understanding of the causal relationship between urban growth patterns and sustainable development. In particular, to find empirical evidence of the sustainability effects of urban growth patterns through a comparative analysis of urban areas with different urban growth patterns over time will contribute to identifying the pros and cons of each different urban growth pattern in terms of sustainability, identifying the factors influencing such a process, and thus help to incorporate sustainability issues into the planning process. However, lacking are empirical tests of specified hypotheses on the relationship between urban growth and sustainability. Empirical evidence from test of specified hypotheses needs to be added to understand the various contexts in which urban growth patterns and urban sustainability interact.

Cities make their efforts to enhance sustainability through a variety of policy options and approaches addressing economic, social and environmental concerns. The effectiveness of policies and programs needs to be evaluated from the perspective of sustainability on a regular basis and various sustainability issues should be fully incorporated into the planning process. In addition, a wide range of participants, including local, state, and federal governments, nonprofit organizations, businesses, citizens, and NGOs, are involved in the process of pursuing sustainability. In this respect, promotion of cooperation among various stakeholders should be a key element for management towards urban sustainability.

2.5 Measuring Progress Toward Sustainable Development

2.5.1 Approaches to Measuring and Analyzing Sustainability

Measuring and analyzing the progress of a society towards sustainable development helps to identify its main strengths and weaknesses and the priority issues, and also provides the basis for monitoring and evaluating the effectiveness of a strategy for achieving sustainable development (OECD, 2002b). There are three main approaches to measuring and analyzing progress towards sustainable development: accounts, narrative assessments not based upon indicators, and indicator-based assessments (OECD, 2002b).

Accounts are constructions of raw data, converted to a common unit such as money, area or energy. In general, accounts refer to one or a narrow set of indicators and include the system of national accounts (covering the market economy), the ecological footprint (covering resource consumption), and energy and material accounts (covering physical exchanges between the economy and the environment) (OECD, 2002b). A typical example of this approach is the measurement of a green GDP (gross domestic product), a popular term for environmentally adjusted gross domestic product. The concept of green GDP was motivated by the concern that the traditional measure of GDP provides only a partial picture of changes in welfare – capturing mainly elements transacted in markets (World Bank, 2003). It tries to modify national accounts to include environmental damages, environmental services, and changes in stocks of natural capital (World Bank, 2003). The advantage of accounts is that they are directly comparable with the GDP, the most widely used measurement of national performance. However, its drawback as a strategic tool for assessing sustainability is that many costs and benefits have no market value, and calculation of the accounts is highly technical and thus leaves little room for wide stakeholder participation (OECD, 2002b).

Another example of this approach is the ecological footprint that estimates the biologically productive area necessary to support current consumption patterns, given prevailing technical and economic processes (Holmberg, Lundqvist, Robert, & Wackernagel, 1999). This method is popular among ecologists to measure changes in natural capital stocks over time. An ecological footprint is a measure of how much land and water is needed to produce the resources we consume and to dispose of the waste we produce (Kahn, 2005). The ecological footprint approach is easy to grasp. But it does not take into account substitution possibilities by assuming that current production and consumption patterns will persist (Kahn, 2005).

Narrative assessments are mainly built around the combination of text, maps, graphics and tabular data. They include state of the environment reports and a variety of other reports such as the World Bank's World Development Reports. Narrative assessments are the most familiar and flexible approach to measurement and analysis. This approach has the high potential for participation because the assessment can be tailored to the technical skills of participants (OECD, 2002b). Because of unsystematic choice of topics, the topics covered may change between reporting periods, preventing the identification of trends and thus reducing the usefulness for strategy development and monitoring (OECD, 2002b).

Indicator-based assessments are organized around a broad set of indicators to deal with the wide array of issues necessary for a portrayal of sustainable development. By using the same set of indicators over time, later assessments can be compared with previous ones, providing consistent coverage from one reporting period to another. Comprehensive and consistent coverage, along with systematic choice of issues and their indicators, enables priority issues and strengths and weaknesses of performance to be easily identified (OECD, 2002b). In this respect, this approach is useful for decision-making. Some indicator-based assessments attempt to combine their indicators into indices. For example, Well-being Assessment combines human indicators into a Human Well-being Index (HWI) and ecosystem indicators into an Ecosystem Well-being Index (EWI), which are combined graphically into a Well-being Index – the intersection of the HWI and EWI on the Barometer of Sustainability (Prescott-Allen, 2001).

As Table II-1 shows, these three approaches differ in their potential for transparency (ease of detecting value judgments and construction of the assessment), consistency over time (comparability of successive assessments), participation (the more technical the method, the less scope for participation), and usefulness for decision-making (clarity with which performance and priorities are revealed). In general, indicator-based assessments are potentially more transparent, consistent and useful for decision-making than accounts and narrative assessments. This study takes an indicator-based approach to measuring and analyzing progress towards urban sustainability in study areas.

Table II-1. Three main approaches to measuring and analyzing sustainability.

	Approaches		
	Accounts	Narrative Assessments	Indicator-based Assessments
Examples	• Green GDP • Ecological Footprint	• World Development Reports • State of Environment Reports	• Well-being Assessment • UNCSD Indicators of Sustainable Development
Potential for transparency	Low	Medium	High
Potential for consistency	High	Low	High
Potential for participation	Low	High	Medium
Usefulness for decision-making	Medium	Medium	High

Source: OECD (2002c).

2.5.2 Functions of Sustainable Development Indicators

Indicators are measures of assessing progress toward a target, or the performance of a policy or plan (Miller, 2004). Sustainable development indicators monitor the condition of an economic-environmental-social system to provide a basis for assessing whether policies, plans and programs have the desired effects (Miller, 2004). Sustainable development indicators are useful in planning, clarifying policy objectives and priorities, budgeting, and communicating with the public as well as assessing performance (OECD, 2000). Sustainable development indicators are also used to raise awareness about the inter-linkages and trade-offs among the three dimensions (economic, environmental and social concerns) of sustainable development and about the longer term implications of current decisions and behaviors (OECD, 2004).

Agenda 21 underlines the need to develop sustainability indicators in Chapter 40: ‘Indicators of sustainable development need to be developed to provide solid bases for decision making at all levels and to contribute to a self-regulating sustainability of integrated environment and development systems.' Sustainable development indicators help achieve the goals of sustainability. International organizations, nations and cities have developed and used sustainability indicators to gauge their progress toward becoming more sustainable and to provide a road map for reaching sustainable development goals.

2.5.3 Criteria for Selecting Sustainable Development Indicators

Some attempts to present guidelines for choosing indicators of sustainable development have been made. OECD (2002c) presented three criteria for selecting indicators of sustainable development: representative, reliable, and feasible:

- **Representative**: an indicator should cover the most important parts of the component concerned; show trends over time and differences between places and groups of people.

- **Reliable**: an indicator should be accurate; be measured in a standardized way; be well founded; directly reflect the objective of the element or sub-element concerned.

- **Feasible**: an indicator should depend on data that are readily available (as maps, statistics or both) or obtainable at reasonable cost.

OECD (1993) used three criteria in developing environmental indicators for environmental performance reviews: policy relevance and utility for users; analytical soundness; and measurability:

- **Policy relevance and utility for users**: an environmental indicator should provide a representative picture of environmental conditions, pressures on the environment or society's response; be simple, easy to interpret and able to show trends over time; be responsive to changes in the environment and related human activities; provide a basis for international comparisons; be either national in scope or applicable to regional environmental issues of national significance; have a threshold or reference value against which to compare it so that users can assess the significance of the values associated with it.

• **Analytical soundness**: an environmental indicator should be theoretically well founded in technical and scientific terms; be based on international standards and international consensus about its validity; and lend itself to being linked to economic model, forecasting and information systems.

• **Measurability**: the data required to support the indicator should be readily available or made available at a reasonable cost/benefit ratio; adequately documented and of known quality; and updated at regular intervals in accordance with reliable procedures.

International Network for Environmental Compliance and Enforcement presented nine criteria for the indicator project: transparent, effective, informative, comparable, policy relevant, credible, compatible, technologically sophisticated, and measurable. The USEPA used six criteria for performance measures: relevant, transparent, credible, feasible, functional, and comprehensive. In sum, indicators are selected according to their pertinence for the purposes their users want them to serve. As OECD (2002c) points out, indicator selection is a matter of balancing various criteria.

2.5.4 The Bellagio Principles for Assessment

In 1996, an international group of measurement practitioners and researchers met in Bellagio, Italy to review progress and synthesize the insights gained from ongoing efforts. They endorsed 10 principles as guidelines for the practical assessment of progress toward sustainable development. The principles are as follows (Hardi & Zdan, 1997):

1. **Guiding vision and goals**: assessment of progress toward sustainable development should be guided by a clear vision of sustainable development and goals that define that vision.

2. **Holistic perspective**: assessment of progress toward sustainable development should: include review of the whole system as well as its parts; consider the well-being of social, ecological, and economic sub-systems, their state as well as the direction and rate of change of that state, of their component parts, and the interaction between parts; consider both positive and negative consequences of human activity, in a way that reflects the costs and benefits for human and ecological systems, in monetary and non-monetary terms.

3. **Essential elements**: assessment of progress toward sustainable development should: consider equity and disparity within the current population and between present and future generations, dealing with such concerns as resource use, over-consumption and poverty, human rights, and access to services, as appropriate; consider the ecological conditions on which life depends; consider economic development and other, non-market activities that contribute to human/social well-being.

4. **Adequate scope**: assessment of progress toward sustainable development should: adopt a time horizon long enough to capture both human and ecosystem time scales thus responding to needs of future generations as well as those current to short term decision-making; define the space of study large enough to include not only local but also long distance impacts on people and ecosystems; build on historic and current conditions to anticipate future conditions - where we want to go, where we could go.

5. **Practical focus**: assessment of progress toward sustainable development should be based on: an explicit set of categories or an organizing framework that links vision and goals to indicators and assessment criteria; a limited number of key

issues for analysis; a limited number of indicators or indicator combinations to provide a clearer signal of progress; standardizing measurement wherever possible to permit comparison; comparing indicator values to targets, reference values, ranges, thresholds, or direction of trends, as appropriate.

6. **Openness**: assessment of progress toward sustainable development should: make the methods and data that are used accessible to all; make explicit all judgments, assumptions, and uncertainties in data and interpretations.

7. **Effective communication**: assessment of progress toward sustainable development should: be designed to address the needs of the audience and set of users; draw from indicators and other tools that are stimulating and serve to engage decision-makers; aim, from the outset, for simplicity in structure and use of clear and plain language.

8. **Broad participation**: assessment of progress toward sustainable development should: obtain broad representation of key grass-roots, professional, technical and social groups, including youth, women, and indigenous people - to ensure recognition of diverse and changing values; ensure the participation of decision-makers to secure a firm link to adopted policies and resulting action.

9. **Ongoing assessment**: assessment of progress toward sustainable development should: develop a capacity for repeated measurement to determine trends; be iterative, adaptive, and responsive to change and uncertainty because systems are complex and change frequently; adjust goals, frameworks, and indicators as new insights are gained; promote development of collective learning and feedback to decision-making.

10. **Institutional capacity**: continuity of assessing progress toward sustainable development should be assured by: clearly assigning responsibility and providing ongoing support in the decision-making process; providing institutional capacity for data collection, maintenance, and documentation; supporting development of local assessment capacity.

The Bellagio Principles are recognized as an international standard for designing and evaluating measurement systems. The above ten principles serve as guidelines for the selection and design of indicators, their interpretation and communication of the result as well as the assessment of progress toward sustainable development (Hardi & Zdan, 1997).

2.5.5 Sustainable Development Indicator Initiatives: International

In 1995 the UNCSD adopted a work program on indicators of sustainable development with the aim of developing, by 2001, a set of indicators for use in national decision-making. In 1996 the UNCSD proposed a list of 134 indicators of sustainable development which was defined by reference to the principles and policy guidance provided by Agenda 21. The UNCSD list has been recognized as a good point of departure for a national sustainable development indicators program.

Between 1996 and 1999, 22 volunteering countries from all regions of the world, including Austria, France, Germany, and United Kingdom, participated in the testing process to gain experience with the selection and development of sustainable development indicators and to assess their application and suitability to assist decision–making at the national level (United Nations, 2001). As a result of the international testing phase, the number of indicators has been reduced from the suggested preliminary list of 134 indicators used in the testing phase. In total, 59 indicators were included in the UNCSD 2000 Core Set: social dimension (20 indicators); environmental dimension (19 indicators); economic dimension (14 indicators); institutional dimension (6 indicators). Problems associated with duplication, lack of relevance, and absence of widely accepted methodologies have largely been eliminated (United Nations, 2001).

The OECD developed the Core Set of 33 indicators to monitor environmental progress, to review environmental performance and to measure progress toward sustainable development. The Core Set consists of 18 environmental indicators and 15 socio-economic indicators. Table II-2 lists the OECD core indicators.

Table II-2. The OECD core set of indicators.

Environmental Indicators			
Climate change	1. CO_2 emission intensities	Water resources	11. Intensity of use of water resources
	2. Greenhouse gas concentrations		12. Public water supply and price
Ozone layer Depletion	3. Ozone depleting substances	Forest resources	13. Intensity of use of forest resources
	4. Stratospheric ozone		14. Forest and wooded land
Air quality	5. Air emission intensities	Fish resources	15. Fish catches and consumption: national
	6. Urban air quality		16. Fish catches and consumption: global and regional
Waste	7. Waste generation	Biodiversity	17. Threatened species
	8. Waste recycling		18. Protected areas
Water quality	9. River quality		
	10. Waste water treatment		
Socio-Economic Indicators			
GDP and population	19. Gross domestic product	Transport	26. Road traffic and vehicle intensities
	20. Population growth and density		27. Road infrastructure densities
Consumption	21. Private consumption		28. Road fuel prices and taxes
	22. Government consumption	Agriculture	29. Intensity of use of nitrogen and phosphate fertilizers
Energy	23. Energy intensities		30. Livestock densities
	24. Energy mix		31. Intensity of use of pesticides
	25. Energy prices	Expenditure	32. Pollution abatement and control expenditure
			33. Official development assistance

Source: OECD (2000).

The Statistical Office of the European Communities (Eurostat), as a contribution to the UN official international testing phase, conducted a pilot study based on the UNCSD list and selected 63 indicators: social dimension (22 indicators); environmental dimension (16 indicators); economic dimension (21 indicators); institutional dimension (4 indicators).

The usefulness of sustainable development indicators can be increased by putting them in an appropriate context or framework. The most widely accepted frameworks are the Pressure-State-Response (PSR) model and the Driving force–State–Response (DSR) model. The PSR model, developed by the OECD, is based on the cause-effect relationships between economic activities, environmental and selected social conditions (OECD, 2000). The PSR model divides indicators into three categories: pressure, state, and response. This framework assumes that human activities exert "pressures" on the environment and affect its quality and the quantity of natural resources ("state"); societies respond to these changes through environmental, economic and social policies and through changes in awareness and behavior ("societal response") (OECD, 2000).

The PSR model has been used by the OECD and other national and international organizations mainly for environmental performance monitoring. The PSR model helps decision makers and the public view environmental and economic issues as interrelated and thus provides a tool of selecting and organizing indicators in a way useful for decision makers and the public (OECD, 2000). Figure II-1 shows a conceptual framework for urban sustainability performance indicator based upon the PSR framework.

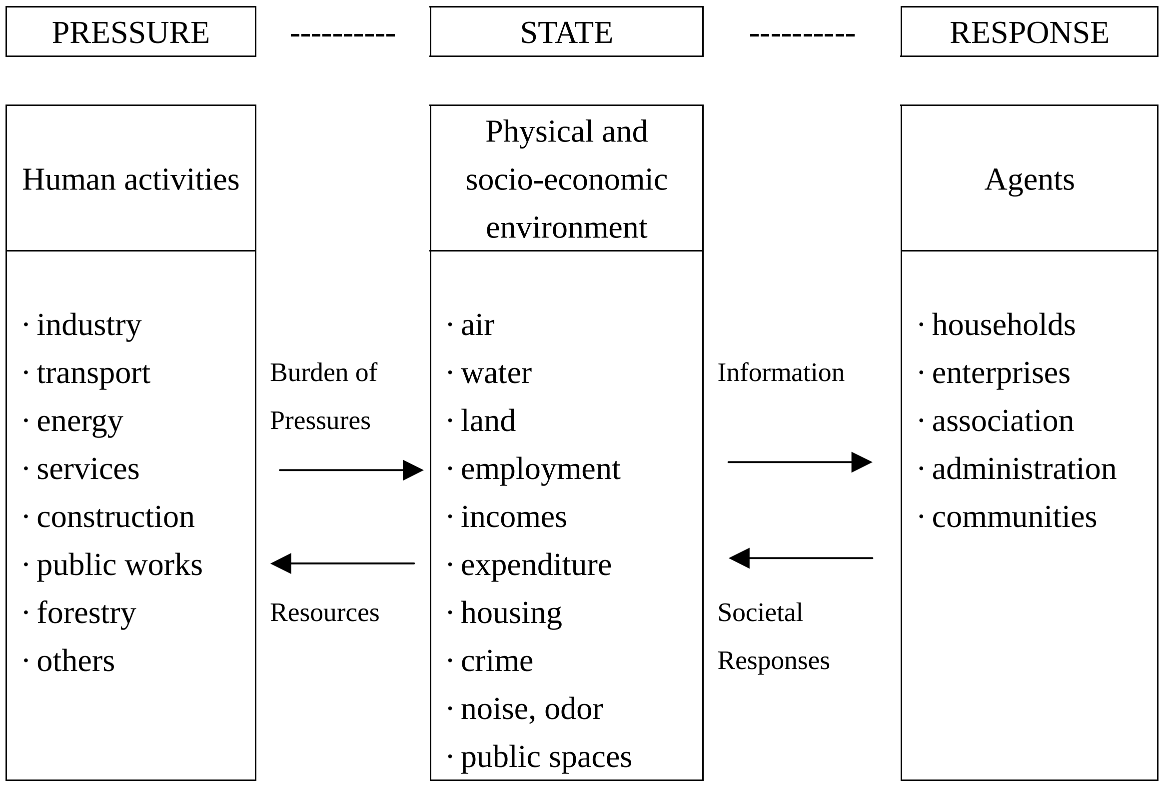

Figure II-1. A conceptual framework for urban sustainability performance indicator. Source: OECD (1997).

The PSR model and modified versions are widely used by government agencies and institutional indicator projects, including UNCSD's Core Set of Indicators, World Bank's Environmental Performance Indicators, and European Union's EuroStat Environmental Pressure Indicators, etc. Typical examples of adjusted versions of the PSR model are the Driving force–State–Response (DSR) model used by the UNCSD in its work on sustainable development indicators and the Driving force–Pressure–State–Impact–Response (DPSIR) model used by the European Environment Agency. The DSR model allows for a better inclusion of non-environmental variables.

2.5.6 Sustainable Development Indicator Initiatives: Local

Sustainable Seattle Indicators Project

Sustainable Seattle is a volunteer citizen's network and civic forum. It is acknowledged worldwide as a leader in developing sustainability indicators based upon a combination of citizen involvement combined with advice from technical experts. Many of the sustainability projects used Sustainable Seattle as a model for their own initiatives. The process of developing indicators adopted by Sustainable Seattle, along with the resulting set of indicators, has influenced community indicators projects in the U.S. and around the world. The sustainable Seattle project began in 1990 as a grassroots effort with the aim of improving economic, environmental and social vitality. The aim of the first project of Sustainable Settle was to develop a set of indicators. Through a three-year citizens' effort, the indicators project selected a set of 40 sustainability indicators which deal with environmental, social, and economic factors in a balanced way (Sustainable Seattle, 1998).

As shown in Table II-3, the indicators are grouped into five categories: environment (7 indicators); population and resources (7 indicators); economy (10 indicators); youth and education (8 indicators), and health and community (8 indicators). Sustainable Seattle has published status reports using their own sustainability indicators in 1993, 1995 and 1998, respectively. The 1998 report showed both progress and problems. Of the 40 trends surveyed, there were eleven indicators (air quality, water consumption, energy use per dollar of income, unemployment, voter participation, etc.) moving Seattle toward sustainability. On the other hand, eight indicators (solid waste generated and recycled, vehicle miles traveled and fuel consumption, distribution of personal income, children living in poverty, etc.) were moving Seattle away from sustainability. Eleven indicators

Table II-3. The indicators of sustainable Seattle.

Category	Indicator	Category	Indicator
Environment	1. Wild salmon	Economy	21. Housing affordability
	2. Ecological health		22. Children living in poverty
	3. Soil erosion		23. Emergency room use for non-ER purposes
	4. Air quality		24. Community reinvestment
	5. Pedestrian- and bicycle-friendly streets	Youth and Education	25. High school graduation
	6. Open space near urban villages		26. Ethnic diversity of teachers
	7. Impervious surfaces		27. Arts instruction
Population and Resources	8. Population		28. Volunteer involvement in schools
	9. Water consumption		29. Juvenile crime
	10. Solid waste generated and recycled		30. Youth involvement in community service
	11. Pollution prevention		31. Equity in justice
	12. Local farm production		32. Adult literacy
	13. Vehicle miles traveled and fuel consumption	Health and Community	33. Low birth-weight infants
	14. Renewable and Nonrenewable energy use		34. Asthma hospitalizations for children
Economy	15. Energy use per dollar of income		35. Voter participation
	16. Employment concentration		36. Library and community center usage
	17. Unemployment		37. Public participation in the arts
	18. Distribution of personal income		38. Gardening activity
	19. Health care expenditure		39. Neighborliness
	20. Work required for basic needs		40. Perceived quality of life

Source: Sustainable Seattle (1998).

(wild salmon, soil erosion, population, housing affordability, etc.) were neutral and 10 indictors did not have sufficient data to reveal a trend. The Sustainable Seattle Indicators Project took an indicator-based assessment approach, and did not attempt to combine its sustainability indicators into indices.

Meanwhile, in King County, where Seattle is located, the Metropolitan King County Growth Management Planning Council (GMPC) formed the Benchmark Task Force in 1995 to draft indicators useful in monitoring and assessing progress on countywide planning policies. Sustainable Seattle's model of community indicators was a point of departure for this project. GMPC adopted 45 indicators which provided the framework for a series of King County Benchmark Reports (GMPC, 1996, 2000).

The indicators are classified into five categories: economic development (8 indicators); environment (12 indicators); affordable housing (9 indicators); land use (11 indicators); and transportation (5 indicators). Indicators are described in terms of progress on desired levels of achievement of the countywide planning policies. According to the 2004-2005 progress reports (King County, 2004, 2005), thirteen indicators (acres of urban parks and open space, water consumption, etc.) have improved and eleven (percentage of population below the poverty level, vehicle miles traveled per year, etc.) worsened. Nineteen indicators (real wages per worker, acres in forest land, etc.) remained stable.

Central Texas Sustainability Indictors Project

The Central Texas Sustainability Indictors Project, launched in 1997, is a community-based effort to develop a set of indicators. Its aim was to provide information about the progress toward sustainability in the Austin region (Bastrop, Caldwell, Hays, Travis, and Williamson Counties). The fifth annual report, published in 2004, measured progress toward sustainability in the region based on 42 indicators. As shown in Table II-4, the indicators are grouped into eight categories: public safety (3 indicators); education & children (6 indicators); opportunity (5 indicators); civic engagement (4 indicators); economy (9 indicators); health (3 indicators); natural resources (7 indicators); land use/mobility (5 indicators).

Table II-4. Central Texas sustainability indicators.

Category	Indicator	Category	Indicator
Public Safety	1. Community safety	Economy	22. Exporting industries
	2. Safe families		23. Labor availability
	3. Equity in law enforcement		24. Diversity of employers
Education and Children	4. Child care – access		25. Job availability
	5. Child care – quality		26. Entrepreneurship
	6. Schools – quality		27. Technical innovation
	7. Schools – equity in educations	Health	28. Health insurance coverage
	8. Schools – academic performance		29. Health status – physical
	9. Higher education		30. Health status – mental
Opportunity	10. Affordable housing – ownership	Natural Resources	31. Water consumption
	11. Access to home loans		32. Water quality
	12. Affordable housing – rental		33. Energy use
	13. English proficiency		34. Attractiveness of the landscape
	14. Diversity in elected leadership		35. Air quality
Civic Engagement	15. Philanthropy & volunteerism		36. Solid waste
	16. Participation in the arts		37. Hazardous materials
	17. Neighborliness	Land Use/Mobility	38. Density of new development
	18. Civic participation		39. Rural land
Economy	19. Household income		40. Publicly-owned open space
	20. Cost of living		41. Time spent commuting
	21. Diversity of industries		42. Vehicle miles traveled

Source: Central Texas Sustainability Indictors Project (2004).

The Austin region was one of the fastest growing in the United States, ranking 5th of 280 metropolitan regions with a growth rate of 47.7% between 1990 and 2000 (over 400,000 people) (Central Texas Sustainability Indicators Project, 2004). Continued population growth was reflected in many of sustainability indicators. Of the 42 indicators examined, only five indicators (community safety, affordable housing-rental, labor availability, technical innovation, energy use) showed positive progress towards sustainability. On the other hand, 26 indicators (household income, diversity of employers, air quality, etc.) were classified as ‘keep watch’ and 10 indicators (higher education, civic participation, job availability, etc.) were classified as ‘needs action’. Like the Sustainable Seattle Indicators Project, the Central Texas Sustainability Indicators Project also took an indicator-based assessment approach, and did not attempt to combine its sustainability indicators into indices.

Santa Monica Sustainable City Plan

Santa Monica, California has also been successful in developing a set of sustainable development indictors and using those indicators to guide urban policy. Santa Monica’s City Council adopted the Sustainable City Program in 1994 to ensure that Santa Monica can continue to meet its current economic, social and environmental needs without compromising the ability of future generations to do the same. In 2003, City Council adopted an updated and expanded version of the program called the Santa Monica Sustainable City Plan, which represents the community’s vision of Santa Monica as a sustainable city. The Sustainable City Plan includes a number of indicators that have been developed to measure progress toward meeting the goals in each area (resource conservation: 8 indicators, environmental & public health: 12 indicators, transportation: 10 indicators, economic development: 8 indicators, open space & land use: 5 indicators, housing: 5 indicators, community education & civic participation: 8 indicators, human dignity: 10 indicators).

Based upon analysis of the indicator data for eight goal areas, Santa Monica published its first annual report card in 2005, which presents a snapshot of the city's progress toward meeting its Sustainable City Plan goals. The grades given for each goal area are: resource conservation (C), environmental & public health (B), transportation (C-), economic development (B), open space & land use (B+), housing (D-), community education & civic participation (B+), and human dignity (N/A) (City of Santa Monica, 2005b).

Portland Sustainability Initiative

Portland, Oregon takes an aggressive stance on driving toward the goal of creating a sustainable city. Portland has one of the most impressive sustainability initiatives of any major U.S. city. The city adopted ten sustainable city principles in 1994 that reflected a long-term commitment of the city government to pursue a variety of specific policies, and created the Office of Sustainable Development, which provides leadership and coordination for conservation and sustainable development programs.

The most important part of the city's sustainability effort can be found in its Comprehensive Plan. Sustainability represents a high priority in the city's Comprehensive

Plan and sustainability goals are an integral part of the city's Plan (Portney, 2003). To achieve sustainability, Portland has adopted an approach to zoning that aggressively takes the environmental protection into consideration in its land use regulation (Portney, 2003).

As part of the city's sustainability initiative, Portland created 'sustainability benchmarks', which were designed to compare how the city is doing to a select group of other cities (Austin, Charlotte, Cincinnati, Denver, Kansas City, Minneapolis/St. Paul, Phoenix, Sacramento, and Seattle) (City of Portland, 2000). The benchmarks are based upon twelve indicators: air quality, carbon dioxide emissions, vehicle miles traveled, travel rate index, toxics release inventory, percentage of urban tree cover and total green space, recycling rate, percent of residents in poverty, percentage of households owning their own home, employment growth in the central city relative to the suburbs, city share of metropolitan area building permits over time, stringency of state energy codes (City of Portland, 2000). According to the 2000 report, Portland was above the average for the other cities in air quality, carbon dioxide emissions, urban tree cover and green space, and solid waste recycling rate, but was below average in vehicle miles traveled, traffic congestion, and releases of toxic chemicals.

San Francisco Sustainability Plan

In 1996, Sustainable City, a community-based nonprofit organization dedicated to achieving a sustainable future for San Francisco, produced the Sustainability Plan for the City of San Francisco and in 1997, the San Francisco Board of Supervisors passed a resolution endorsing the Plan. The Plan provides goals, objectives and specific actions to achieve a more sustainable future in the following 15 topic areas: air quality; biodiversity; energy, climate change, and ozone depletion; food and agriculture; hazardous materials; human health; parks, open spaces and streetscapes; solid waste; transportation; water and wastewater; economy and economic development; environmental justice; municipal expenditures; public information and education; risk management (Sustainable City, 1996). Sustainable City has taken on the task of implementing the sustainability plan.

The Sustainability Plan includes a sustainability indicators project that provides measures of progress in each of the topic areas. An integral part of the Plan is a section on indicators. Over 50 indicators were chosen in topics addressed in the Plan. For example, indicators for air quality are: the number of existing buildings that join the Building Air Quality Alliance Program; the number of people going to clinics for respiratory problems; the percentage of new cars registered which are alternatively fueled (e.g., low emission vehicles, ultra-low emission vehicles, or electric vehicles). Economy indicators include the percentage of people employed in San Francisco who live in San Francisco, the number of San Francisco enterprises adopting ISO 14000 standards, the difference between the highest neighborhood unemployment rate and the full employment rate, and others. The San Francisco indicators project covers a wide variety of topics.

Vision 2020 Sustainability Indicators Program: Hamilton, Ontario, Canada

VISION 2020 is the City of Hamilton's long-term vision of a sustainable future shared by local government, citizens, businesses, groups and organizations. The purpose of the Vision 2020 Indicators Program is to provide information to guide the decision-making, and to generate action to create a sustainable community. A set of indicators was created to measure specific aspects of each of the fourteen VISION 2020 theme areas: local economy, agriculture & the rural economy, natural areas & corridors, improving the quality of water resources, reducing & managing waste, consuming less energy, improving air quality & climate change, changing our mode of transportation, land use in the urban area, arts & heritage, personal health & well-being, safety & security, education, and community well-being & capacity building. According to the 2004 progress report, half of the 35 indicators showed progress towards sustainability, five were uncertain and twelve needed improvement (City of Hamilton, 2004).

SustainLane US City Rankings

In November 2004 through May 2005, SustainLane, a San Francisco-based community-generated internet media site providing information on healthy and sustainable living, examined 25 U.S. cities to measure their relative levels of sustainability based upon 12 major categories (transportation, air quality, tap water quality, Leadership in Environmental & Energy Design building, food & agriculture, zoning, land use, solid waste, city innovation, planning, energy/climate, knowledge base). Overall rankings (see Table II-5) were developed by averaging each city’s performance across 12 major categories (SustainLane, 2005). 25 cities were classified into five groups according to their sustainability scores. San Francisco and Portland were classified as ‘Sustainable Leader (score: 1~5)’ and nine cities, including Berkeley, Seattle, Santa Monica, and Austin, were classified as ‘Moving To Sustainability (score: 6-10)’.

Table II-5. US city sustainability rankings.

Rank	City	Score	Rank	City	Score
1	San Francisco	4.875	14	Philadelphia	11.833
2	Portland	4.916	15	San Jose	12.291
3	Berkeley	6.75	16	Sacramento	12.416
4	Seattle	6.791	17	Scottsdale	13
5	Santa Monica	8	18	Los Angeles	13.208
6	Austin	8.33	19	Pittsburgh	14.583
7	New York	8.541	20	Atlanta	15.2916
8	Chicago	8.75	21	Chattanooga	15.7
9	Oakland	9.375	22	Jacksonville	16.166
10	Minneapolis	9.5416	23	Albuquerque	16.208
11	Denver	9.5416	24	Detroit	17
12	Boston	10.25	25	Houston	18.93
13	Madison	11.2			

Source: SustainLane (2005).

Conclusion

To measure and assess progress toward urban sustainability is an integral part of the process of enhancing sustainability of cities and examining the effect of urban growth and change on urban sustainability. As introduced above, attempts have been made to develop sustainable development indicators and assess progress toward sustainable development at the local level.

As Deakin, Mitchell, and Lombardi (2002) point out, the technical aspects of urban sustainability assessment such as assessment techniques and analytical procedures, are important for addressing urban sustainability issues in a pragmatic fashion. Most of the urban sustainability indicator projects mainly depend upon indicator-based assessments and have limitations in showing the overall sustainability conditions over time and in identifying the factors affecting the process. However, using indicator-based assessments in combination with statistical analysis methods can greatly help to provide a clear overall picture of the entire human and environmental conditions over time and to identity the factors affecting the process. Proper assessment and analysis techniques facilitate systematic comparison of cities, which leads to a more complete understanding of urban sustainability (Portney, 2003).

2.6 Sustainable Development Concerns in Korea

2.6.1 Increased Awareness of Sustainable Development

Korea has achieved a high rate of economic growth since the 1960s. Much of the growth was attributable to a series of economic development plans that focused on developing and exploiting effective public-private sector collaboration to direct limited resources into strategic sectors of the economy with export potentials. Unbalanced growth has been strategically promoted in the name of economic efficiency.

However, growth-oriented policies have been challenged since the 1990s. Rapid economic growth has been accompanied with environmental degradation and social inequity (PCSD, 2002). Unbalanced growth resulted in high concentration of people and economic activities in Seoul and the Seoul Metropolitan Region, which caused a number of urban problems: shortage of affordable housing; land price spiral and land speculation; inadequate urban services; and environmental degradation (Ahn & Ohn, 2001; Kwon, 2001). Rapid influx of people into large urban areas has been largely responsible for causing environmental and social issues.

Planning requires an integrated approach to the economic, social and environmental concerns. However, many of the past planning efforts in Korea focused on economic development with only a marginal consideration given to social equity, balanced spatial growth, and environmental protection (Kwon, 2001). Economic growth would no longer be meaningful unless it contributes to pursuing social equity and environmental protection. People are paying attention to social and environmental consequences arising from growth-oriented policies. Under this circumstance, economic growth strategies have to be made consistent with sustainable development which aims at achieving three main objectives: economic development, social equity and environmental protection. In this respect, sustainability goals need to be an integral part of planning process in Korea.

2.6.2 Government Responses to Sustainability Challenges

Since the 1992 Rio Summit, the Korean government has formulated a variety of policies and programs to mitigate the negative environmental and social impacts of economic growth. In order to implement the measures outlined in Agenda 21, the Korean government formulated the National Action Plan for Agenda 21 in 1996. In 2002, the government adopted 10 sectoral strategic plans for sustainable development: land use management and human settlements; social welfare; industry; environmental science and technology; agriculture and rural development; forests; nature conservation and biodiversity; marine sector; water quality management; air pollution control and transportation. A set of indicators of sustainable development was also developed to monitor and assess progress toward sustainable development at the national level in the following areas: economy (14 indicators); society (17 indicators); environment (17 indicators); institution (5 indicators). In 2000, the Presidential Commission on Sustainable Development was established to respond to increasing global concern for sustainable development and to create long-term strategies for achieving sustainable development by building an effective partnership between government and civil society (PCSD, 2002).

As of 2004, a total of 213 out of 234 local governments adopted a local Agenda 21, a program for implementing sustainable development at the local level. A few cities have attempted to develop sustainable development indicators. For instance, the City of Seoul developed 27 indicators in 2001 and the City of Chungju in North Chungcheong Province developed 80 indicators in 2002. Achieving urban sustainability requires the development of sustainability goals and indicators, target setting and monitoring, along with policies aimed at improving sustainability. However, most local governments in Korea don’t have such a system of monitoring and assessing progress toward sustainability.

CHAPTER III

METHODOLOGY

3.1 Introduction

This chapter presents the methodology used in this study. It starts with the selection of study areas. The set of sustainability indicators for measuring sustainability in the study areas is presented in the second section and the indicator relevance is also discussed for each indicator based mainly upon sustainable development principles presented in Agenda 21. The third section discusses data collection and data quality. The fourth section introduces the methodology for measuring urban sustainability and statistical methods used in testing research hypotheses.

3.2 Study Areas

The subject areas are all 31 municipalities (cities and counties) comprising Gyeonggi Province in the Seoul Metropolitan Region. Comparison is expected to provide a relative scale of urban sustainability and to help explain the processes and causation contributing to sustainability in the study areas. The study areas are introduced in detail in Chapter IV.

3.3 Selection of Urban Sustainability Indicators

3.3.1 Urban Sustainability Indicators for the Study

As stated above, some attempts have been made to develop a set of indicators with the aim of measuring and assessing progress towards sustainability at the local level. Based upon three components (economic development, environmental protection, and social equity) of the concept of sustainable development, the existing indicators deal with a variety of aspects of cities: population, housing, economy, land use, natural resources, environment, transportation, education, safety and health, civic engagement, and so on (Central Texas Sustainability Indicators Project, 2004; City of Hamilton, 2004; City of Portland, 2000; City of Santa Monica, 2005a; Newman & Kenworthy, 1999; Sustainable Seattle, 1998).

Based upon the literature review on sustainable development indicators, this study evaluates and modifies the current indicators, and then selects a final set of indicators based upon data comparability and quality. This study uses 38 sustainability indicators which are classified into eight categories: population and household; land use; transportation; safety and health; housing and education; environment; economy; and community engagement. The urban sustainability indicators used in this study are presented in Table III-1.

Table III-1. Urban sustainability indicators for the study.

Category	Indicator	Calculation	Relationship to sustainability
Population and Household	Population growth rate (X1)	Total population change during a period of time (1985-1990, 1990-1995, 1995-2000) / total population at the beginning of each period (1985, 1990, 1995)	-
	Population density (X2)	Total population / total area (㎢)	-
	Average household size (X3)	Total population / total Households	+
	Percentage of single-parent households (X4)	Total single-parent households / total households	-
Land Use	Percentage of agricultural area (X5)	Area of agricultural land / total area (㎢)	+
	Percentage of forest area (X6)	Area of forest / total area (㎢)	+
	Percentage of greenbelt area (X7)	Area of greenbelt / total area (㎢)	+
	Public park acreage per capita (X8)	Area of public parks (㎡) / total Population	+
Transportation	Car ownership rate (X9)	Total cars / total households	-
	Percentage of commuters who walk or use bicycles (X10)	Number of commuters who walk or use bicycles / total commuters	+
	Percentage of commuters who use cars (X11)	Number of commuters who use cars / total Commuters	-
	Time spent commuting (X12)	Total one-way commute time (minutes) / total commuters	-
Safety and Health	Number of crimes per 1,000 inhabitants (X13)	(Total reported crimes / total population)×1,000	-
	Number of fires per 10,000 inhabitants (X14)	(Total fires / total population) ×10,000	-
	Percentage of population with access to safe drinking water (X15)	Number of residents with access to drinking water supply facilities / total population	+
	Access to sewage disposal facilities (X16)	Completed public sewage pipeline network / planned public sewage pipeline network	+
	Availability of medical services per 1,000 inhabitants (X17)	(Total medical personnel / total population) × 1,000	+

Table III-1 (continued).

Housing and Education	Number of housing units per 100 households (X18)	(Total housing units / total households) × 100	+
	Home ownership rate (X19)	Number of households with their own dwellings / total households	+
	Level of educational Attainment (X20)	Number of college completion adults / total population	+
	Number of students per teacher (X21)	Number of primary, middle, high school students / total primary, middle, high school teachers	-
	Number of students per classroom (X22)	Number of primary, middle, high school students / total primary, middle, high school classrooms	-
Environment	Waste generation per capita (X23)	Amount of waste generation (㎏ per day) / total population	-
	Waste recycling rate (X24)	Amount of recycled waste / amount of waste generation	+
	Water consumption per capita (X25)	Amount of water consumption (liter per day) / total population	-
	Energy consumption per household (X26)	Amount of electric power consumption (mwh per year) / total households	-
	Number of air pollution facilities per 10,000 inhabitants (X27)	(Number of air and water pollution facilities / total population) ×10,000	-
	Number of water pollution facilities per 10,000 inhabitants (X28)	(Number of air and water pollution facilities / total population) ×10,000	-
	Use of chemical fertilizers (X29)	Amount of chemical fertilizers (metric ton) / area of agricultural land (㎢)	-
Economy	Gross regional domestic product per capita (X30)	Gross regional domestic product / total Population	+
	Number of people living in poverty per 1,000 inhabitants (X31)	(Number of poor people receiving the government’s aid by the law / total population)×1,000	-
	Women’s job opportunity (X32)	Number of employed women / total employed population	+
	Employment density (X33)	(Number of employed persons / total population)×100	+
	Employment diversification (X34)	Number of persons employed in each year’s top three largest industry sectors / total employed population	-
	Economic self-sufficiency (X35)	Number of persons who are employed at the place of residence / total employed population	+
Community Engagement	Number of NGOs per 10,000 inhabitants (X36)	(Number of NGOs / total population) × 10,000	+
	Voter participation rate (X37)	Number of registered voters participating in general election / total registered voters	+
	Annual library visits per Capita (X38)	Total annual library visits / total Population	+

Table III-1 also shows the relationship of each indicator to urban sustainability. The plus sign indicates that the higher the number is, the more positive the relationship to sustainability is. The minus sign indicates that the higher the number is, the more negative the relationship to sustainability is.

3.3.2 Indicator Relevance

Category 1: Population and Household

Indicator 1: Population growth rate

Humans have a significant impact on the Earth and its resources. The growth of population is one of the main determinants affecting the use of land, water, air, energy and other resources. Thus, population change is viewed as one of significant signals as countries try to reduce poverty, achieve economic development, and improve environmental quality (UNCSD, 2001). Rapid population growth can lead to unsustainable living conditions and increased pressure on the environment (UNCSD, 2001). Chapter 5 of Agenda 21 (demographic dynamics and sustainability) underlines the importance of population growth as a key driving force affecting long-term sustainability, especially in conjunction with poverty, lack of access to resources, unsustainable patterns of production and consumption, or in ecologically sensitive areas.

Indicator 2: Population density

The impact of humans on the environment is related to the spatial distribution of the population. Population density, which measures the concentration of the population in a given area, is one of the widely used state indicators of sustainable development. Increasing population density may threaten sustainability of protected forest areas and ecologically fragile lands and also cause more demand for housing, transportation and infrastructure for sanitation and waste management (EU, 2001). Chapter 7 of Agenda 21 (promoting sustainable human settlement development) refers to the ‘area of urban formal and informal settlements’ as an indicator of human living conditions.

Indicator 3: Average household size

Family characteristics, which reflect social trends in marriage, family formation and dissolution, have a direct impact on the social, economic and environmental patterns of our daily lives (EU, 2001). For instance, they are closely linked to the pattern of consumption of goods and services in the residential sector. Household size affects energy use (lighting, heating, fuel for cooking, etc.), water use, and solid waste disposal.

Indicator 4: Percentage of single-parent households

Noting that children in both developing and developed countries are highly vulnerable to the effects of environmental degradation, Agenda 21 recommends governments to take active steps to implement programs for children in the areas of environment and development, especially health, nutrition, education, literacy and poverty alleviation in Chapter 25 (children and youth in sustainable development). Agenda 21 also recommends governments to improve the environment for children at the household and community level in that children become effective focal points for sensitization of communities to environmental issues. The EU (2001) highlights the importance of child welfare by including an indicator on children living in single-parent families.

Category 2: Land Use

Indicator 5: Percentage of agricultural area

Agricultural land is a finite natural resource. There are many intangible benefits associated with the preservation of agricultural land, including aesthetic, open space and sense of place. Agricultural land also provides habitat for many different species of plants and animals. Chapter 10 of Agenda 21 (integrated approach to the planning and management of land resources) encourages governments to ensure that policies support the best possible land use and sustainable management of land resources, giving particular attention to the role of agricultural land.

Indicator 6: Percentage of forest area

Forests are important for water catchment, carbon storage, and social and landscape reasons. In addition, forests can be biodiverse habitats, home to many different species. Forested land also contributes to soil conservation and water management by allowing groundwater to recharge. Chapter 11 of Agenda 21 (combating deforestation) underlines the protection, sustainable management and conservation of all forests, and the greening of degraded areas, through forest rehabilitation, afforestation, reforestation and other rehabilitative means, to maintain or restore the ecological balance and to expand the contribution of forests to human needs and welfare.

Indicator 7: Percentage of greenbelt area

A greenbelt usually refers to an area of largely undeveloped wild or agricultural land surrounding a city or urban region that is designated for preservation (Pendall, Martin, & Fulton, 2002). Greenbelts constrain the geographical expansion of existing urban areas. A greenbelt policy serves as a useful instrument to maintain the openness of the countryside around areas of growth, protect the natural environment and prevent urban sprawl. Greenbelt land also contributes to improving bio-diversity and amenity value. In the Seoul Metropolitan Region, the greenbelt policy was introduced in 1971 to protect the countryside and enhance its quality rather than create urban sprawl (Kim & Kim, 2000). To maintain the amount of greenbelt land, development projects have not been allowed on land designated as greenbelt.

Indicator 8: Public park acreage per capita

Public spaces such as public parks and squares are an integral part of the physical and social fabric of any successful and sustainable community. Public parks provide a variety of social, economic and environmental benefits. For instance, public parks provide affordable recreational opportunities to urban dwellers while protecting environmental quality and improving urban amenities. Since an increasing proportion of the population lives in towns and cities, public parks become even more important. Public parks are recognized as a major element in the quality of human life and the sustainability of cities (Chiesura, 2004). Chapter 7 of Agenda 21 (promoting sustainable human settlement development) encourages countries to develop and support the implementation of improved land management practices that deal comprehensively with potentially competing land requirements for agriculture, industry, transport, urban development, green spaces, preserves and other vital needs.

Category 3: Transportation

Indicator 9: Car ownership rate

According to Agenda 21, transport accounts for about 30 percent of commercial energy consumption and for about 60 percent of total global consumption of liquid petroleum. Rapid motorization creates increasing problems such as accidents and injury, noise, air pollution, traffic congestion and energy consumption. The more people drive, the further people may move away from sustainability. A rapid expansion in the number of motor vehicles needs more roads which take up valuable land and reduce wildlife habitats and open space.

Indicator 10: Percentage of commuters who walk or use bicycles

Agenda 21 underlines the promotion of efficient and environmentally sound urban transport systems in Chapter 7 (promoting sustainable human settlement development). Agenda 21 recommends governments to encourage non-motorized modes of transport through safe and sufficient infrastructure such as pedestrian- and bicycle- friendly streets. Walking and bicycling are a key part of a sustainable transport system in that they contribute to the reduction of energy and natural resources consumption and air pollution.

Indicator 11: Percentage of commuters who use cars

Agenda 21 recommends that countries adopt urban transport programs favoring high-occupancy public transport to discourage vehicle use. Vehicle use and gasoline consumption are linked to excessive use of nonrenewable resources, air pollution, and loss of open space and wildlife habitat (Sustainable Seattle, 1998). In particular, excessive gasoline consumption contributes to increased greenhouse gas production and global warming. A good public transport system is vital in reducing car travel and improving the access to services.

Indicator 12: Time spent commuting

It is important for residents to have access to affordable and reliable transportation alternatives that allow them to travel efficiently. Noting that rapid motorization and insufficient investments in traffic management and infrastructure cause negative impacts such as air pollution, congestion, energy consumption and loss of productivity, Chapter 7 of Agenda 21 (promoting sustainable human settlement development) highlights the promotion of sustainable transport systems in human settlements. A decrease in time spent commuting would reflect expanded transport infrastructure, traffic operation improvements, reduced travel distances and wider use of public transport.

Category 4: Safety and Health

Indicator 13: Number of crimes per 1,000 inhabitants

Crime is not only a problem of illegal behavior but also a phenomenon closely associated with economic and social development (EU, 2001; UNCSD, 2001). Crime trends are linked to various issues such as unemployment, poverty and social exclusion. If development is to be sustainable, it should be able to provide social conditions that would enable people to lead peaceful and secure lives (UNCSD, 2001). Imbalanced or inadequately planned development can contribute to a rise in crime especially where fruits of development are not equitably distributed among the people (UNCSD, 2001). Chapter 6 of Agenda 21 (protecting and promoting human health conditions) addresses the importance of improvement in indicators on social problems such as violence and crime that indicate underlying social disorders.

Indicator 14: Number of fires per 10,000 inhabitants

Fires take the form of forest fires and residential/commercial/industrial structure fires. Forests provide multiple benefits to human society including timber production, conservation of water, soil and biodiversity, carbon sinks. However, as Chapter 11 of Agenda 21 points out, many countries are confronted with the effects of fire damage on their forests due to weaknesses in the policies, methods and mechanisms adopted to support and develop the ecological, economic, social and cultural roles of trees, forests and forest lands. Structure fires such as residential, commercial and industrial also cause civilian deaths, injuries and property loss. Effective fire prevention and management is vital to the protection of natural resources and the promotion of healthy and safe communities.

Indicator 15: Percentage of population with access to safe drinking water

Safe drinking water is vital for improving human health and promoting sustainable urban development and is also crucial to many human activities. Many diseases and deaths in developing countries are linked to the consumption of contaminated water. Chapter 7 (promoting sustainable human settlement development) and Chapter 18 (protection of the quality and supply of freshwater resources; application of integrated approaches to the development, management and use of water resources) of Agenda 21 underline the importance of a safe drinking water supply.

Indicator 16: Access to sewage disposal facilities

Chapter 7 and Chapter 21 (environmentally sound management of solid wastes and sewage-related issues) of Agenda 21 state the need to provide and improve sanitation services for minimizing the health and environmental impacts of inadequate sewage treatment. Extending and improving sewage collection and safe disposal services are crucial to improving human health conditions and controlling land and water contamination.

Indicator 17: Availability of medical services per 1,000 inhabitants

As Agenda 21 states, health and development are interrelated in that sound development is not possible without a healthy population. The health conditions of people can be improved through development. However, urban growth sometimes outstrips the capacity of local governments to provide adequate health services that the people need.

Chapter 6 of Agenda 21 (protecting and promoting human health conditions) underlines the improvement in health service indicators and the preparation of community-based health and health-related workers.

Category 5: Housing and Education

Indicator 18: Number of housing units per 100 households

As Chapter 7 of Agenda 21 states, access to adequate housing is essential to people's physical, psychological, social and economic well-being. Agenda 21 emphasizes the provision of adequate housing for all through housing development and improvement that is environmentally sound. In particular, most growing cities in developing countries experience shortages of housing and face the constant challenge of meeting the growing housing needs. In this respect, expanding the supply of decent, affordable housing is one of key tasks governments need to carry out in developing countries.

Indicator 19: Home ownership rate

Lack of home ownership as well as lack of available housing creates negative effects for a sustainable and healthy community. Promotion of home ownership has been at the heart of governments' policy objectives in most countries. With an increasing population in growing cities, it is vital to develop plans that promote home ownership as foundations for a sustainable community. Home ownership can be promoted through a sufficient supply of affordable housing, easy access to home loans, and stable home prices.

Indicator 20: Level of educational attainment

Chapter 36 of Agenda 21 recognizes the promotion of education, public awareness and training as being critical for improving the capacity of the population to address sustainable development issues and fostering greater motivation towards sustainable development. Education is regarded as one of the most important tools to facilitate the transition to a more sustainable society by increasing public awareness of environment and development problems (UNCSD, 2001). Education also has a direct effect on employment opportunities, income and public involvement in decision-making.

Indicator 21: Number of students per teacher

Chapter 25 of Agenda 21 (children and youth in sustainable development) stresses the role of children and youth in the protection of the environment and the promotion of economic and social development. Agenda 21 recommends that governments ensure that children and youth have access to appropriate education. Improved standards of education provide them with opportunities necessary to fulfill their personal, economic and social aspirations and potentials. Improving the quality of education contributes to the development of each student's unique potential.

Indicator 22: Number of students per classroom

Education is one of the most powerful forces for economic development. Education can also lead to improvements in family health, economic and social status. As mentioned above, Agenda 21 emphasizes the need to ensure access for children and youth to education in Chapter 25. Improved educational environments such as well-developed school facilities are needed to ensure access to basic education.

Category 6: Environment

Indicator 23: Waste generation per capita

Environmentally sound waste management is one of the environmental issues of major concern in maintaining and improving the quality of the environment. The generation of waste is linked to resource depletion and environmental pollution (EU, 2001). Landfills of waste have adverse effects on the environment such as surface water, groundwater, soil, air and human health. Incineration, the most common alternative to landfill, has also drawbacks such as toxic gaseous emissions and the need to dispose of the ash produced. Chapter 21 of Agenda 21 (environmentally sound management of solid wastes and sewage-related issues) puts emphasis on the need to stabilize or minimize the amount of waste generated.

Indicator 24: Waste recycling rate

Waste recycling is an important component for a sustainable approach to waste management. The greater the amount of recycled waste, the smaller is the disposal need (e.g., landfill and incineration) and overall resource depletion (EU, 2001). Chapter 21 of Agenda 21 underlines the maximization of recycling of wastes and recommends countries to establish voluntary targets for the proportion of waste recycled.

Indicator 25: Water consumption per capita

Water is one of basic natural resources necessary for individual needs and economic purposes such as agriculture, urban development and industrial activities. Water is also important for protecting aquatic ecosystems as the habitat for aquatic species. The sustainable use of water is vital for assuring future socio-economic development in that water consumption is a major pressure on water resources (EU, 2001). Chapter 18 of Agenda 21 (protection of the quality and supply of freshwater resources; application of integrated approaches to the development, management and use of water resources) also emphasizes the sustainable and rational utilization of water resources.

Indicator 26: Energy consumption per household

As Agenda 21 states, reducing the amount of energy and materials consumed per unit in the production of goods and services can contribute to the alleviation of environmental stress and to greater economic productivity. Chapter 7 of Agenda 21 (promoting sustainable human settlement development) emphasizes the need to increase the efficiency of energy use and to extend the provision of more energy-efficient technology and renewable energy in order to reduce the negative impacts of energy production and use on human health and on the environment.

Indicator 27: Number of air pollution facilities per 10,000 inhabitants

Air pollution has adverse health impacts on humans. As the Rio Declaration states, in order to achieve sustainable development, environmental protection should be an integral part of the development process. However, in many cases, development causes air pollution. Industry, power generation and motor vehicles release pollutants. Agenda 21 underlines the protection of the atmosphere in Chapter 9.

Indicator 28: Number of water pollution facilities per 10,000 inhabitants

Water pollution also threatens environmental sustainability and can have harmful effects on human health. Poor water quality is one of the most serious pollution issues in many urban areas. Agenda 21 underlines the protection of the quality of freshwater resources in Chapter 18. Protection of clean water is a multidimensional endeavor involving various sectors of economic activities.

Indicator 29: Use of chemical fertilizers

Farming practices are an important source of pressure on the environment. In particular, excessive use of chemical fertilizers causes various environmental problems such as water pollution, soil degradation, loss of habitat and biodiversity (EU, 2001). Chapter 14 of Agenda 21 (promoting sustainable agriculture and rural development) addresses a sustainable supply of plant nutrients to increase future yields without harming the environment and soil productivity. Many countries try to introduce specific incentive schemes to encourage farmers to adopt environmental practices to maintain the countryside, to make production less intensive, to avoid polluting practices and to protect biodiversity (EU, 2001).

Category 7: Economy

Indicator 30: Gross regional domestic product per capita

Growth in material prosperity is an important part of economic development. Gross regional domestic product (GRDP) measures this growth over time. GRDP is the monetary value of a city or region's market and non-market activities in a given year. GRDP per capita provides a good proxy of the material wealth of citizens. As GRDP per capita grows, more resources are available to invest in environmental protection and social welfare measures. However, greater wealth is also linked to greater use of energy and materials. Though there is no explicit target growth rate for GRDP per capita, it is an important measure for the economic and development aspects of sustainable development, including the pattern of consumption and production and the use of renewable resources (UNCSD, 2001).

Indicator 31: Number of people living in poverty per 1,000 inhabitants

Poverty is both a cause and a consequence of unsustainable societies (EU, 2001). Noting that the eradication of poverty and hunger remains major challenges everywhere, Chapter 3 of Agenda 21 (combating poverty) emphasizes that an anti-poverty strategy is one of the basic conditions for ensuring sustainable development. Agenda 21 underlines the need to develop and implement an effective strategy for tackling the problems of poverty, development and environment simultaneously.

Indicator 32: Women's job opportunity

Women and sustainable development issues are an essential component of Agenda 21. Women are among nine major groups (indigenous people, local authorities, trade unions, business and industry, farmers and so on) whose involvement is necessary to achieve sustainable development. However, the role of women in achieving sustainable development has been limited by a variety of barriers such as discrimination and lack of access to education and equal employment. Agenda 21 emphasizes the active participation of women in economic and political decision-making to ensure the successful implementation of Agenda 21. Chapter 24 of Agenda 21 (global action for women towards sustainable and equitable development) states the need to support and strengthen equal employment opportunities and equitable remuneration for women in the formal and informal sectors. It recommends that governments develop policies necessary to promote reconciliation of work and family life including the provision of child-and dependent-care.

Indicator 33: Employment density

For achieving a sustainable society, it is important to ensure that residents have satisfactory job opportunities. Job opportunity is a traditional measure of economic vitality. That is, increased level of job opportunity leads to a vital economy. Chapter 3 of Agenda 21 recommends governments to establish measures that will directly or indirectly generate remunerative employment and productive occupational opportunities on a scale sufficient to take care of prospective increases in the labor force.

Indicator 34: Employment diversification

In order to minimize the negative effects of cyclical downturns and changing market conditions, local economy needs to be diverse. If employment concentrates in a few key industries, a downturn in key industries is likely to have serious repercussions throughout the local economy (Sustainable Seattle, 1998). The resulting cuts in tax revenues and consumer spending can cause other layoffs, driving up homelessness, poverty, and crime rates. A society experiencing such shocks is less likely to have the vision or resources to adequately support sustainable development (Sustainable Seattle, 1998).

Indicator 35: Economic self-sufficiency

Lack of economic self-sufficiency of a city can be caused by various factors such as lack of employment centers, lack of adequate infrastructure including transportation and telecommunication, lack of incentives for entrepreneurial activities, and lack of affordable housing. Lack of economic self-sufficiency causes many negative consequences. For instance, suburban cities without self-sufficient economic base function as bedroom towns for major cities, which results in increase in travel distance (Kim, 2005). Increasing distances between work and home force people to drive more, which harms air quality and causes more energy consumption (National Association of Counties et al., 2001). Promoting economic self-sufficiency contributes to improving the quality of life of residents by providing more job opportunity, and creating a prosperous, diverse and sustainable economy.

Category 8: Community Engagement

Indicator 36: Number of non-governmental organizations per 10,000 inhabitants

Chapter 27 of Agenda 21 underlines the importance of the role of non-governmental organizations (NGOs) as partners in achieving sustainable development. NGOs, which represent a number of interests and concerns, play an important role in the discussion of sustainability issues and the development of solutions (OECD, 2002a). To ensure that the potential contribution of NGOs is realized, Agenda 21 stresses the communication and cooperation between international organizations, national and local governments and NGOs. NGOs' diverse experience and capacity are of importance to the implementation and review of sustainable development.

Indicator 37: Voter participation rate

In a democratic society, the level of voter turnout reflects the commitment that people have to the political system and the extent to which all segments of society participate in key decision-making (Central Texas Sustainability Indicators Project, 2004). Decreasing voter turnout can indicate that people feel disempowered and believe their voters won't make a difference, or that the government system is organized to discourage civic participation. Public participation in decision-making is one of the key principles for achieving sustainable development addressed in Agenda 21.

Indicator 38: Annual library visits per capita

Public libraries foster personal and community development by making learning and knowledge accessible to all. In the information age, libraries are becoming increasingly significant. Well-used libraries are indicators of a sustainable society (Sustainable Seattle, 1998). Library usage is closely tied to other signs of social sustainability such as literacy and education, political interest and knowledge, and intellectual vitality. The gains in literacy and information exchange that grow from accessible and frequently used libraries help invigorate public debates and public participation (Sustainable Seattle, 1998).

3.4 Data Collection and Data Quality

The time span of this study covers the period 1990-2000. The indicator data were collected for 31 municipalities in Gyeonggi Province for each of the following years: 1990, 1995, and 2000. The main indicator data sources were government publications: the Population and Housing Census Reports by the National Statistical Office; and the Statistical Yearbooks by local governments.

The Census dataset included indicator data on population, housing, employment, transportation and so on. In the Census, basic items (20 items) on population, households and housing were surveyed on the basis of complete enumeration, whereas additional items (30 items) on commuters and students, economic activity, rent, etc., were surveyed for the households of a 10% sample of enumeration districts. The accuracy of the data consists of validity and reliability. Validity concerns itself with the question of whether the study is actually measuring what is supposed to be measured. This is generally an issue of questionnaire construction and definition of terms whose information is available in the appendix of the Census reports. The questions were well-organized to measure necessary information on population, housing, employment, etc., and the terms were clearly defined. Reliability concerns itself with the average amount of variation among the results of many replications of the same study. The dataset was reliable in that the questionnaires consisted of the conventional and typical questions, and the National Statistical Office standardized administration instructions and also used the same estimation technique. Taking into account the size of 10% sample, the sampling errors were almost negligible. That is, the Census achieved sufficient sample sizes for selected enumeration districts while maintaining efficiency. There was also no problem with the response rate (98%).

Other indicator data such as environment and land use were obtained mainly from local government publications. Local governments use the standardized definition of terms and criteria in publishing their statistical yearbooks, which are set by the central government. Local governments submit their local data to central and provincial governments every year, which in turn check the data for the publication of national and provincial statistical yearbooks. Data accuracy is tested by the mutual review between levels of government.

3.5 Statistical Analysis Method

3.5.1 Constructing a Composite Index of Sustainability

Data Transformation

The collected data for each indicator were transformed and standardized because the indicators were measured in a variety of different units such as percentages, persons, or square meter. Standardization makes each indicator have a mean of 0 and a standard deviation of 1. The widely used way of transforming data is to construct a z-score for each indicator (World Economic Forum, 2005). Z-scores help to compare relative values of different variables for a case (Kerr, Hall, & Kozub, 2002; Norusis, 2002). The formula for converting a given value of x into its corresponding z-score is as follows:

$$Z_X = \frac{X - \mu_X}{\sigma_X}$$

where Z_X is the z-score, X is the value for particular observation, μ_x is the mean, σ_x is the standard deviation.

Z-scores were calculated for each of 38 sustainability indicators for each study area using SPSS 12.0 statistical software in this study (see Appendix A, Appendix B, and Appendix C). Where the larger indicator value is more sustainable than the smaller value:

$$Z_X = \frac{X - \mu_X}{\sigma_X}$$

Where the smaller indicator value is more sustainable than the larger value:

$$Z_X = \frac{\mu_X - X}{\sigma_X}$$

Data Aggregation

To compare the level of sustainability in the study areas, this study attempted to derive a composite score of sustainability for each municipality. As mentioned in Chapter

II, sustainability covers a wide variety of aspects of urban places, which makes it difficult to weight different indicators accurately in the process of deriving a composite score of sustainability. Thus, this study has used z-scores to assign each study area a scaled sustainability value. The z-scores for each of the sustainability indicators were then aggregated to derive a composite sustainability index for each municipality.

In general, an index can be thought of as a compound indicator combining several lower-level of indicators (OECD, 2002b). Interlinked sets of indicators and aggregations of indicators into indices are needed for understanding the complexity of sustainable development (OECD, 2002b). Assessments of sustainability that combine their indicators into indices are easy to interpret and use in decision-making, and can also communicate their findings readily (OECD, 2002b). When indicators of sustainable development are combined into indices, they can provide a clear picture of the entire human and environmental conditions, reveal key interrelationships between major components, and promote analysis of main strengths and weaknesses (OECD, 2002b). Typical examples of indices include the Living Planet Index (World Wildlife Fund, 2004), the German Environmental Barometer and Index (Federal Environmental Agency, 2002), the Ecological Footprint (Global Footprint Network, 2005), and the Environmental Sustainability Index (World Economic Forum, 2005).

3.5.2 T-test and ANOVA

This study conducts t-tests and one-way ANOVA (Analysis of Variance) to test Hypotheses 1 to 4. The t-test is performed to test the null hypothesis that there is no difference between the means of two groups. An ANOVA tests the difference between the means of several groups. That is, whereas the t-test is limited to situations in which there are only two levels of the independent variable (i.e., two experimental groups), an ANOVA is used to analyze situations in which there are several independent variables (Field, 2000; George & Mallery, 2003). The t-tests and ANOVA are conducted in this study to examine if there are differences between the mean levels of sustainability among the subject areas. This study also uses a post-hoc comparison using Scheffe's method to find out where the differences are – which groups are significantly different from each other and which are not.

3.5.3 Factor Analysis

Factor analysis is conducted to test Hypothesis 5 in this study. Factor analysis is a statistical technique that is used to (1) uncover the latent structure (dimensions) of a set of variables, or (2) reduce a data set from a group of interrelated variables into a smaller set of uncorrelated factors (Field, 2000).

There are several criteria used to decide whether a factor is statistically important. First, eigenvalues associated with a factor indicate the substantive importance of that factor. The eigenvalues associated with each factor, which are widely used to select the number of factors, are a measure of the amount of the variance accounted for by each factor (Field, 2000; Hoyle & Duvall, 2004; Jolliffe, 2002; World Economic Forum, 2005). By default, SPSS uses Kaiser's criterion of retaining factors with eigenvalues greater than 1 (Field, 2000). SPSS displays the eigenvalue in terms of the percentage of variance explained.

Another common approach that is used for deciding on the number of factors to include in a factor analysis is to examine a scree plot of the eigenvalues plotted against the factor numbers (Field, 2000; Hoyle & Duvall, 2004; Jolliffe, 2002; World Economic Forum, 2005). The scree plot represents the magnitude of the eigenvalues for each factor number. Generally, there will be a few factors with high eigenvalues, and many factors with relatively low eigenvalues. Thus there is a point of inflexion in the curve followed by a tailing off (Field, 2002). A scree plot is typically interpreted as follows: the number of factors appropriate for a particular analysis is the number of factors before the plotted line turns sharply right (Field, 2000; Hoyle & Duvall, 2004; World Economic Forum, 2005).

Factors are extracted using the principal component analysis and rotated to orthogonal simple structure by the varimax method. The principle component analysis transforms a set of variables to a set of uncorrelated principle components. Rotation has the effect of optimizing the factor structure. The varimax method for rotation, which is most commonly used in factor analysis, provides the minimum number of variables that have high loadings on a factor so that the extracted factors can be easily interpreted (Norusis, 2002).

Once factors are extracted, the loading of the variable on each factor is calculated. A factor loading is a measure of the contribution a variable makes to a particular factor. That is, the factor loadings of the variables on each factor indicate their importance. The higher the loading of a variable, the more influential it is for explaining variation in the direction of the factor. Based upon the factor loadings, the relative importance of the sustainability indicators with respect to sustainability is analyzed and discussed. This study carries out factor analysis using SPSS 12.0 statistical software to identify the key drivers affecting the patterns of sustainability in the study areas over the period 1990-2000.

CHAPTER IV

GROWTH MANAGEMENT POLICIES AND URBAN GROWTH PATTERNS IN STUDY AREAS

4.1 Introduction

The pattern of urban growth and change inside a metropolitan area is affected by interdependent relationships between the central city and surrounding areas. For the Seoul Metropolitan Region, Seoul has had an enormous effect on the growth and change of surrounding areas in Gyeonggi Province. Therefore, in order to understand the patterns of urban growth and change in the study areas, examining the spatial characteristics and planning practices of the Seoul Metropolitan Region is needed.

This chapter consists of two sections. The first section provides an overview of the Seoul Metropolitan Region and also introduces growth management policies for the Seoul Metropolitan Region. The second section introduces the study areas and describes the patterns of growth and change in the study areas over the 1990-2000 period.

4.2 Growth Management Policies in the Seoul Metropolitan Region

4.2.1 The Historical Development of Seoul

Korea has experienced remarkable economic growth and subsequently enormous spatial transformation since the 1960s. The concentration of population and economic activities toward the capital city has been the most dominant phenomenon. From a preindustrial city devastated by the Korean War (1950-1953), Seoul has rapidly grown to become one of the mega-cities with about 10 million inhabitants. Seoul has served as a national engine of economic growth. The growth of Seoul began in the early 1960s. After the military coup of 1961, the government launched national economic development policies to modernize Korea. The national development agenda shifted from an agrarian economy to export-oriented industries. Seoul, as the nation’s political, economic, cultural and educational center, was the most attractive place for better employment opportunities, education, health and social services (Ahn & Ohn, 2001). Seoul attracted newly emerging manufacturing factories, which consequently accelerated rural-to-urban migration. The Guro industrial park was developed in 1965 to accommodate labor-intensive light industries. As a result, Seoul experienced tremendous growth during the 1960s and 1970s. As shown in Table Ⅳ.1, the population of Seoul increased from 2.4 million in 1960 to 5.4 million in 1970.

A number of policy measures were introduced to prevent explosive population growth in Seoul: development control by a rigid zoning system and designation of the greenbelt; industrial relocation; and dispersal of government offices and colleges from Seoul (Kwon, 2001). The adoption of a greenbelt policy in and around the city limit in 1971 curbed the physical expansion of Seoul and promoted development in the less developed southeastern part of Seoul, which is now characterized by vast apartment complexes, high-rise office buildings, and dense commercial developments.

During the 1980s, Seoul’s hosting of the 1986 Asian Games and the 1988 Summer Olympics prompted urban renewal efforts, along with the expansion of the public infrastructure such as subway lines and roadways. The City of Seoul and the central government implemented many massive housing development projects. Until the mid-1980s, housing developments occurred within a radius of 15㎞ of the center of Seoul and in the late 1980s, new developments took place within 15-25㎞ of the center of Seoul (Lee, 2004). Although the population growth rate of Seoul tapered off throughout the 1980s, the absolute size of the population continued to increase from 8.4 million in 1980 to 10.6 million in 1990.

During the 1990s, in order to increase urban competitiveness in response to globalization processes and to meet the citizen's needs, Seoul implemented many citywide construction projects including subway lines, bridges, and roadways, and private building projects that changed the city's skyline (Kwon & Kim, 2001). During the Asian financial crisis of 1997, Seoul had to face new problems such as unemployment and homelessness (Kwon & Kim, 2001). Continuous technological development accelerated industrial restructuring in Seoul in the 1990s, which was characterized by the growth of high-tech industries and decline of labor-intensive industries. As a result, Seoul has become the center of high-tech industries based upon research institutes, universities, and corporate headquarters (Shin & Byeon, 2001). In particular, the Gangnam area, located in the southeastern part of Seoul, serves as the location for many venture firms.

Due to the continued urban renewal and housing redevelopment projects focusing on replacing substandard, outmoded houses mainly with new apartment units, Seoul experienced enormous spatial transformations throughout the 1990s (Kim, 2004). Those projects contributed to relieving Seoul's chronic housing shortages and improving the living conditions. They also reinforced the central city toward a more compact city by encouraging denser, mixed, and infill development. On the other hand, they contributed to the overcrowdedness of the city and thus put a severe strain on urban infrastructure. The population of Seoul decreased from 10.6 million in 1990 to 9.9 million in 2000.

The opening of the Incheon International Airport in 2001 and the completion of the Seoul-Busan high-speed rail system in 2004 served as a powerful force to strengthen Seoul's position as the center of international economic activities in Northeastern Asia (Kwon & Kim, 2001). Seoul faces two challenges in the 21st century. One is to improve its competitiveness in the process of globalization. As a member of the regional and world city system, Seoul competes among the largest cities around the world. The other is to achieve progress toward sustainable development. Mega-cities are major consumers of natural resources and generators of various forms of waste and pollution (Kwon, 2001). Seoul has experienced many urban problems in the process of its fast growth and change such as traffic congestion, housing shortage, environmental pollution, and fiscal plight, which had a negative effect on the quality of life and sustainability in Seoul. It is important to enhance sustainability of Seoul in that the sustainability forms a substantial basis for urban competitiveness.

4.2.2 The Emergence of the Seoul Metropolitan Region

A metropolitan region consists of the central city and the surrounding areas that have socio-economic interdependency with the central city. The Seoul Metropolitan Region (SMR), one of the most dynamic and rapidly growing urban agglomerations in the world, consists of the Capital City of Seoul, Incheon Metropolitan City and the surrounding Gyeonggi Province. Seoul has spread beyond its boundary and affected urban growth patterns in the wide region surrounding the city since the 1960s (Hill & Kim, 2000). The pattern of metropolitan growth in the SMR is characterized by the predominance of Seoul within the region.

Population distribution and employment location are two important forces that affect metropolitan settlement patterns (Kwon, 2001). The two forces also have an enormous effect on the metropolitan growth process in the SMR. The growth process of the SMR began with the completion of two suburban rail transit systems (Seoul – Incheon corridor and Seoul – Suwon corridor) in 1974. Increased suburban access by rail transit systems prompted urban development along the two transportation corridors. Overpopulated Seoul was not in a position to absorb all the potential in-migrants, given the capital's limited physical size, and consequently people had to locate in the surrounding cities and towns.

A process of population decentralization within the SMR, which occurred simultaneously with a shift in manufacturing employment, emerged from the mid-1980s (Kim & Jung, 2001). The suburban areas within the commuting distance from Seoul began to grow rapidly throughout the 1980s and 1990s, accommodating population and economic activities from Seoul (Lee, 2004). In particular, the construction of five new towns in the late 1980s and early 1990s and the large-scale housing development projects in the 1990s accelerated the growth of suburban areas. Moreover, industrial restructuring and the resulting growth of high-tech industries since the late 1980s have increased the importance of the SMR (Kim & Gallent, 1997). Many urban developments have occurred mainly within 30㎞ radial distance from the center of Seoul in the 1980s and outside of 30㎞ radial distance in the 1990s in the SMR (Kim, 2004; Kim & Jung, 2001).

As a result, as shown in Table IV-1, the population of Incheon Metropolitan City and the Province of Gyeonggi significantly increased from 4.9 million in 1980 to 8 million in 1990 and 11.5 million in 2000, despite the government efforts to curb the growth of the SMR. In the twenty years between 1980 and 2000, the SMR's total population grew by 61% to a total of 21.4 million people.

Table IV-1. Population growth in the SMR.

(1,000 persons)

	1960	1970	1980	1990	2000
Seoul (A)	2,445	5,433	8,364	10,613	9,895
Incheon & Gyeonggi (B)	2,749	3,297	4,934	7,974	11,459
SMR (A+B)	5,194	8,730	13,298	18,587	21,354
Nation	24,989	30,882	37,436	43,411	46,136

Table IV-2 shows the degree of concentration in the SMR in 2003. The physical size of the SMR, which extends outwards over a radius of 70㎞ from the center of Seoul, is relatively small in proportion to the country's total land area, only about 11.8%, yet its population accounts for 47.6% of the total population of Korea. Table IV-2 further illustrates the dominance of the SMR over the nation in many aspects. This heavy concentration of population and socio-economic activities in the SMR has been a major obstacle to a more balanced regional spatial development.

Table IV-2. The degree of concentration in the SMR (2003).

	Nation (A)	SMR (B)	Seoul (C)	Concentration (%)	
				B/A	C/A
Area (㎢)	99,601	11,723	605	11.8	0.6
Population (000s)	48,824	23,240	10,277	47.6	21.1
GRDP (billion won)	516,647	251,709	105,872	48.7	20.5
Manufacturing industry					
- Establishments	110,356	62,553	20,249	56.7	18.4
- Employees (000s)	2,696	1,263	291	46.9	10.8
Service industry					
- Establishments	701,645	330,564	167,791	47.1	23.9
- Employees (000s)	2,856	1,574	956	55.1	33.5
College students (000s)	1,808	689	445	38.1	24.6
Banking					
- Deposits (billion won)	548,098	374,219	278,292	68.3	50.8
- Loans (billion won)	538,261	357,888	236,369	66.5	43.9
Offices for public services	403	344	254	85.4	63.0
Top 100 firms	100	92	78	92.0	78.0
Vehicles (000s)	14,587	6,783	2,776	46.5	19.0

4.2.3 Growth Management Policies in the Seoul Metropolitan Region

The key objective of growth management policies in the SMR was to steer people and industries away from the SMR and to ultimately serve to bring forth a desirable pattern of national physical development (Ahn & Ohn, 2001; Kim & Jung, 2001). The government has worked out a lot of policies to control the rapid growth of Seoul and the SMR. Although the formal policy objective has been unchanged, strategies in practice have been changed over the past decades.

Policies in the 1960s and 1970s

During the 1960s and 1970s, several important laws designed to contain the growth of Seoul were enacted: the Comprehensive National Physical Development Planning Law, the Local Industrial Promotion Law, the National Land Use Management Law, and the Industrial Estate Promotion Law.

The Comprehensive National Physical Development Planning Law of 1963 empowered the central government to formulate a master plan for the nation's physical development (land use, distribution of population, location of industries and so on) at a ten-year interval. The Local Industrial Promotion Law of 1970 aimed to steer manufacturing firms into less populated provincial areas through various measures such as tax incentives. The National Land Use Management Law of 1972 enabled the central government to create a national zoning system for effective land use and industrial distribution, and the Industrial Estate Promotion Law of 1973 assisted development of industrial estates in strategic locations other than the SMR (Ahn & Ohn, 2001). During the 1970s, several industrial new towns (Changwon, Youchon, Gumi, etc.) were built in less developed provincial areas to relocate population and industries from Seoul and also absorb the population and industries heading toward Seoul (Ahn & Ohn, 2001).

One of the most powerful strategies for managing the rapid growth of Seoul was the introduction of a greenbelt policy. In 1971, the central government designated a greenbelt around the city boundary of Seoul as a means to limit the physical growth of Seoul. Since then, the greenbelt policy has been strictly implemented. The greenbelt contributed to curbing the outward expansion of cities and protecting agricultural land and open space. However, under increasing development pressure, it created a leapfrog urban development in areas beyond the greenbelt's outer boundary (Choe, 2004; Lee, Yun, Jun, & Jung, 2000). From the mid-1970s, a new package of policy tools was devised with priority given to regulating manufacturing firms and education institutions which were viewed as the primary forces to attract firms and people (Ahn & Ohn, 2001). College enrollments were strictly controlled in Seoul. Under the Industrial Distribution Law of 1977, no factories were permitted for construction or expansion in Seoul and its immediate vicinity, while the existing ones were required to move out. In the late 1970s, two new towns were developed in the SMR to relocate manufacturing firms (Ansan) and government offices (Gwacheon) located in Seoul.

Policies in the 1980s

The strategies in the 1980s were based upon the Second National Physical Development Plan (1982-1991) and the Capital Region Management Law of 1982. From the broader national perspective, two key strategic concepts were introduced in the Second Plan: the integrated living sphere strategy and the growth center strategy. The former placed emphasis on linking the national urban nodes (cities and towns) with surrounding rural areas to alleviate the intra-regional inequality, and the latter aimed to deal with the problem of interregional inequality by creating enough counter magnets to curb the concentration in the SMR (Ahn & Ohn, 2001).

Under the Capital Region Management Law, the entire SMR was considered as a planning unit and the region-wide land use control system was introduced. The Law aimed at providing an effective guideline for physical development, land use, and arrangement of infrastructure targeted for the entire Seoul Metropolitan Region. The Law contained three important policy tools: the adoption of the Capital Region Management Plan; the creation of the Capital Region Management Committee; and the introduction of the population impact assessment (Lee & Lee, 2004). The main purpose of the Plan was to ensure effective land use, desirable distribution of industrial population and harmonious placement of infrastructure across the SMR. The first Capital Region Management Plan of 1984 divided the Capital Region into five zonal sub-regions: relocation promotion zone, restricted rearrangement zone, development inducement zone, nature preservation zone, and development reservation zone (Park, 1995). The Capital Region Management Committee, chaired by the Prime Minister, reviewed and coordinated regional planning and management issues. The population impact assessment was required for development projects of certain categories to forestall adverse effect upon population growth within the Region.

In 1989, the central government launched a new town development project (1989-1996) which called for the construction of five new towns (Bundang, Ilsan, Pyeongchon, Sanbon, and Joongdong) within about 20㎞ from the center of Seoul just beyond the outer edge of the greenbelt to alleviate the chronic housing shortages.

Policies in the 1990s

In 1993, there was a significant change in the planning and management policy for the SMR. Through the revision of the Capital Region Management Law, the previous five categories of sub-regions were reclassified into three zones (Park, 1995):

(1) Over-concentration Control Zone: where further development would be discouraged by decentralizing population and industries. Establishment of firms,

offices and other facilities would be granted only after meeting specified requirements instead of being approved by the Capital Region Management Committee. Seoul and its environs would be tightly regulated not to permit excess congestion.

(2) Growth Management Zone: where development would be permitted in principle. Factories would be permitted except for large-scale ones. Colleges, public offices, research facilities, industrial estates, residential land clearance projects would be permitted when meeting specified requirements.

(3) Nature Preservation Zone: where development would be restricted in principle. The upper Han River basin would be placed in scrutiny not to contaminate the River. The former tight regulations on other types of development would be relaxed to allow more free-standing establishment.

Under the new zoning system, the formerly rigid regulations were relaxed (Lee & Gee, 1999; Park, 1995). The revised zoning system introduced two measures to minimize the shortcoming of the former system. The first is the total volume management system. Under this system, colleges, firms, offices, industrial estates, and housing site developments would get limited freedom in their location choice within a pre-determined ceiling of different types of development (Ahn & Ohn, 2001). Another measure is the development charge system which is an indirect control measure introduced in place of the formerly outright physical control directed against offices and commercial buildings (Ahn & Ohn, 2001; Lee & Lee, 2004). Under this system, office and commercial buildings are free to be built wherever they choose in Seoul, as far as they pay what is called the development charge, a kind of congestion fee (Ahn & Ohn, 2001).

With the revision of the National Land Use and Management Law in 1993, urban development was allowed in predominantly agricultural areas (officially classified as the

Semi-Agricultural & Forest Zone) beyond the greenbelt areas to increase the supply of housing (Lee, 2004). Thus, a number of small-scale private housing developments occurred along major arterial roads in suburban areas such as Yongin, Paju and Gimpo in Gyeonggi Province without the necessary provision of urban infrastructure, which resulted in the massive conversion of agricultural land into urban uses and the disorderly leapfrog suburbanization (Kim & Jung, 2001; Lee, 2004; Lee & Gee, 1999).

Policies in the 2000s

There was a significant change in the greenbelt policy in the early 2000s. Under the greenbelt system, constructing new buildings and changing existing land uses for purposes other than agriculture were not allowed in the greenbelt areas. Nevertheless, landowners and residents in the greenbelt areas haven't received any compensation and thus their complaints have increased. In order to protect landowners' property rights and to absorb the pressure for urban development, the greenbelt policy was relaxed in the early 2000s. Out of the 14 greenbelts around Seoul and other cities nationwide, the greenbelts of seven small-and-medium sized cities with little or no development pressure were completely lifted and the areas are to be controlled by the zoning regulations. The greenbelt boundaries in seven large cities have been redelineated through environmental assessment based on topography, land suitability and ecological sensitivity. The lands under continued control of the greenbelt are purchased by the central government on request.

As the metropolitanization process continues in the SMR, the need for region-wide planning and management has been increasingly growing (Kwon, 2001). The metropolitan planning system was introduced as a response to this situation through the revision of the Urban Planning Law in 2000. Its main purpose is to set up strict growth control over large cities and their surrounding areas and to guide growth management efforts at the metropolitan level. It also serves as a tool to settle intergovernmental conflicts arising in the process of redelineating the greenbelt boundaries in metropolitan areas (Choe, 2004).

The population of Seoul has decreased since 1990s, but the SMR is growing faster than any other region in Korea. The central government plans to construct a new administrative city in South Chungcheong Province, the central part of South Korea as a sure way to cope with the uncurbed growth of the SMR. The project is to relocate most government offices, including Office of the Prime Minister, from downtown Seoul and Gwacheon to the new city. This project is expected to bring about a significant change in growth management policies in the SMR.

Conclusion

The growth of Seoul and the SMR has been viewed as a symbol of the rapid economic growth of Korea. However, Seoul and the SMR have suffered from many urban problems such as urban sprawl, housing shortage, traffic congestion, high land price and speculation, environmental degradation, and degrading quality of urban amenities (Lee, 2000). Various control policies and measures to limit the excessive growth of Seoul and the SMR have been formulated and implemented over the past decades. In spite of the government's strenuous efforts, there has been the problem of growing inequalities between the SMR and other regions (Ahn & Ohn, 2001; Kwon & Ryu, 2005; Lee, 2000;

Lee & Lee, 2004).

There have been many criticisms on the effectiveness of the previous policies (Choi, 2004; Kim & Jung, 2001). The past policies have sometimes been unrealistic or irrelevant due to the lack of political support, the lack of sufficient governmental investments, or the lack of institutionalized coordination between levels of government (Ahn & Ohn, 2001). The containment policy against the growth of the SMR did not guarantee the automatic growth of less developed provincial areas (Choi, 2004; Kwon, 2001). Sustainability was often sacrificed to economic growth (Kwon, 2001). Public land development projects mainly focusing on the housing supply sometimes neglected local governments' urban policies addressed in their comprehensive plans and thus distorted urban spatial structures in the SMR (Lee, 2004). The consistent and timely policy measures are required to guide and manage the growth of the SMR in an effective and sustainable manner.

The Seoul Metropolitan Region provides unique patterns and processes of urban growth and change compared to developed countries and other developing countries in that the central government has played a critical role in directing the pattern of urban growth and change.

4.3 The Patterns of Growth and Change in Study Areas

4.3.1 Overview of Study Areas

The Seoul Metropolitan Region is composed of Seoul Metropolitan City, Incheon Metropolitan City, and Gyeonggi Province. The study areas are all 31 municipalities (27 cities and 4 counties) comprising Gyeonggi Province. Gyeonggi Province is located in the central-western part of the Korean peninsula and surrounds the Korean capital of Seoul (see Figure IV-1). It is located between longitude 126° and 127° East, and between latitude 36° and 38° North. Gyeonggi Province, which covers an area of 10,189㎢, accounts for approximately 86.9% of the Seoul Metropolitan Region's total land area.

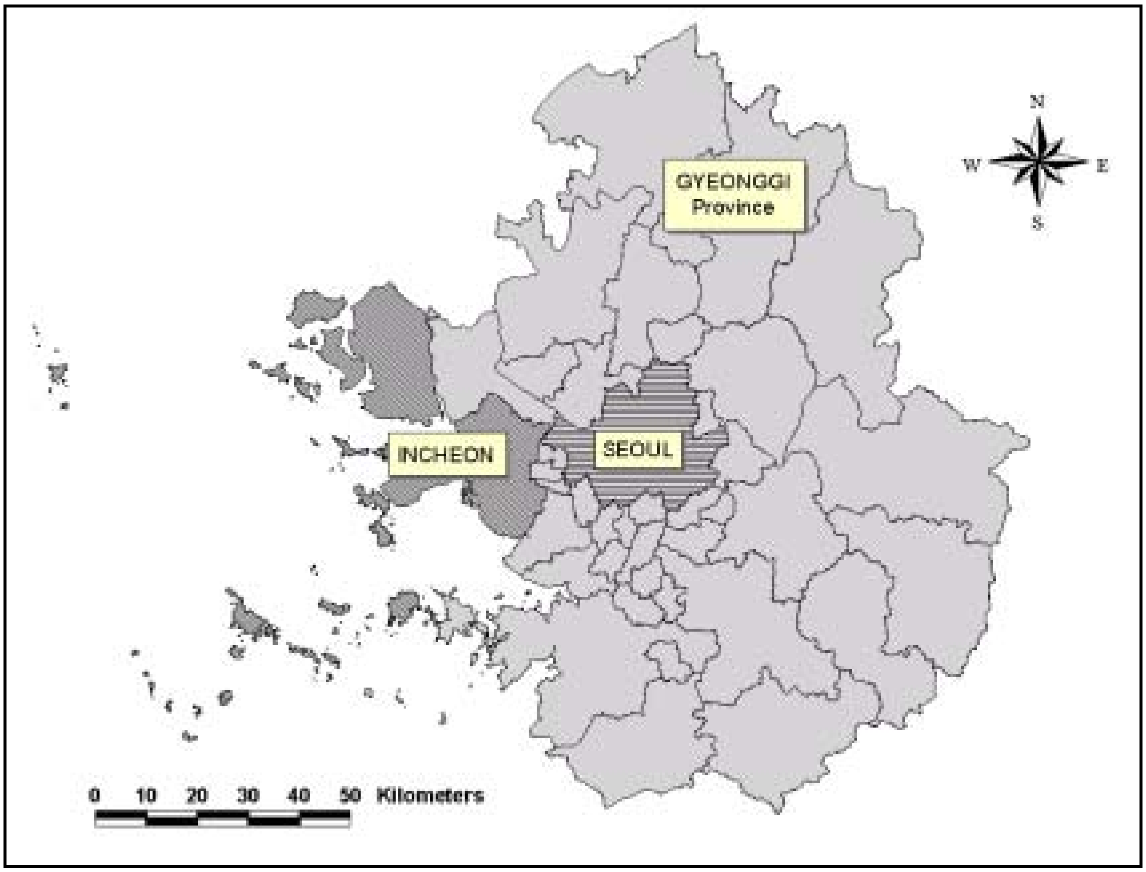

Figure IV-1. Location of study area: Gyeonggi Province.

As stated before, greenbelts were designated around Seoul in 1971 to limit the physical expansion of Seoul and protect agricultural land and open space. Greenbelts consist of a band averaging about 10㎞ wide, beginning about 15㎞ from the center of Seoul (Bengston & Youn, 2006). Gyeonggi Province's greenbelts comprise about 12.7% of its total area. Figure IV-2 shows the location of greenbelts in the Seoul Metropolitan Region. Urban development has been strictly controlled on greenbelt land. As a result, greenbelts have influenced enormously the pattern of urban growth of surrounding areas and the spatial structure of the Seoul Metropolitan Region.

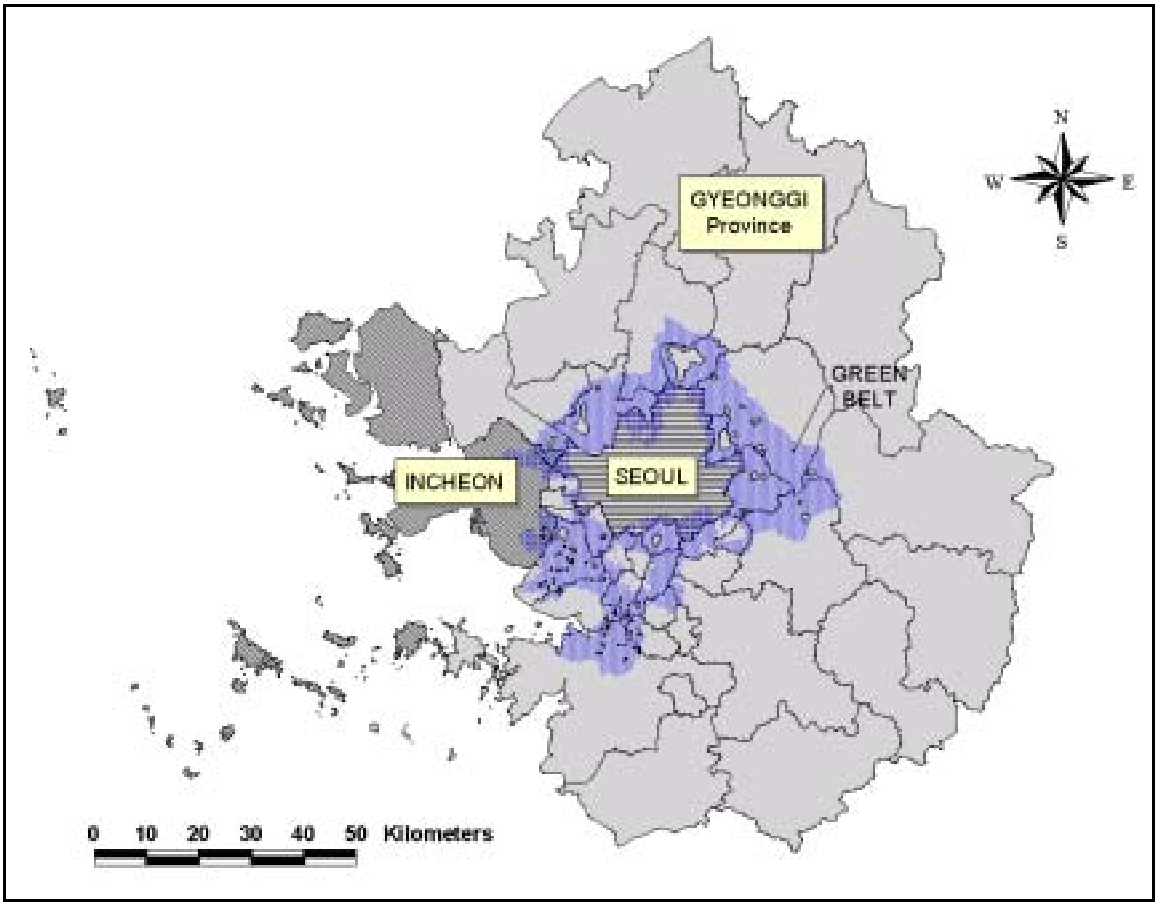

Figure IV-2. Location of greenbelts in the Seoul Metropolitan Region.

As shown in Figure IV-3, the Seoul Metropolitan Region is divided into three zones according to the Capital Region Management Law: over-concentration control zone, growth management zone, and nature preservation zone. As stated before, in the over-concentration control zone, further development is discouraged to decentralize people and economic activities. In the growth management zone, development is permitted. Factories are permitted except for large-scale ones. In the nature preservation zone, development is strictly controlled to protect natural resources such as water and forests.

Figure IV-3. Three zones in the Seoul Metropolitan Region.

Table IV-3 provides an overview of three zones in the Seoul Metropolitan Region.

The over-concentration control zone covers about 17 percent of the Seoul Metropolitan Region, but accounts for about 80 percent of the region's total population. The growth management zone comprises about 50 percent of the region's total area and makes up about 15 percent of the region's total population. The nature preservation zone occupies about 32 percent of the region's total area and accounts for about 4 percent of the region's total population. Gyeonggi Province's over-concentration control zone makes up 9.8 percent of the region's total area and its growth management zone comprises 43.9 percent of the region's total area. Gyeonggi Province's nature preservation zone accounts for 32.7 percent of the region's total area.

Table IV-3. Overview of three zones in the Seoul Metropolitna Region (2005).

		Area (㎢)		Population (1,000 persons)	
			Percent (%)		Percent (%)
Grand total		11,730	100.00	23,782	100.00
Over-concentration control zone	Sub total	1,996	17.02	19,127	80.43
	Seoul	605	5.16	10,297	43.30
	Incheon	238	2.03	2,401	10.10
	Gyeonggi	1,153	9.83	6,429	27.03
Growth management zone	Sub total	5,902	50.32	3,717	15.63
	Seoul	-	-	-	-
	Incheon	755	6.44	231	0.97
	Gyeonggi	5,147	43.88	3,486	14.66
Nature preservation zone	Sub total	3,832	32.67	938	3.94
	Seoul	-	-	-	-
	Incheon	-	-	-	-
	Gyeonggi	3,832	32.67	938	3.94

4.3.2 The Patterns of Growth and Change in Gyeonggi Province

Gyeonggi Province has experienced rapid growth and change during the 1990-2000 period. This section aims to understand the processes by which Gyeonggi Province has evolved over the same period by dealing with the patterns of growth and change in Gyeonggi Province based on descriptive statistics on population, employment, and land use.

Population

As shown in Table IV-4, Gyeonggi Province's population grew by 53.07 percent from 6,062,625 persons in 1990 to 9,280,013 in 2000. In particular, there was a rapid growth of population between 1990 and 1995 (28.85 percent). The three zones in Gyeonggi Province showed a different trend in population growth over the 1990-2000 period. The over-concentration control zone experienced rapid population growth between 1990-1995 (35.68 percent), but its population growth has slowed down to 15.81 percent between 1995 and 2000. During the 1990-2000 period, the over-concentration control zone covered more than 60 percent of the total population of Gyeonggi Province. While the growth management zone's population grew by 20.78 percent between 1990-1995, the zone had a 25.41 percent increase in population between 1995 and 2000. During the 1990-2000 period, the nature preservation zone covered more than 6 percent of the total population. Although the nature preservation zone's population continued to increase during the 1990-2000 period, its growth rate was much lower than that of the other two zones, mainly due to the restriction imposed on land development.

Table IV-4. Population growth of Gyeonggi Province, 1990-2000.

Zone	Population (persons)			Percent Distribution (%)			Growth Rate (%)		
	1990	1995	2000	1990	1995	2000	90-95	95-00	90-00
Total	6,062,625	7,811,468	9,280,013	100.00	100.00	100.00	28.85	18.80	53.07
Over-concentration control zone	3,707,165	5,030,018	5,825,334	61.15	64.39	62.77	35.68	15.81	57.14
Growth management zone	1,905,206	2,301,147	2,885,882	31.43	29.46	31.10	20.78	25.41	51.47
Nature preservation zone	450,254	480,303	568,797	7.43	6.15	6.13	6.67	18.42	26.33

Table IV-5 shows the population growth patterns in Gyeonggi Province by the distance from the center of Seoul. Overall, the municipalities at a distance between 21 and 30㎞ had the highest population growth during the 1990-2000 period (77.66 percent). However, the patterns of population growth varied greatly according to the distance from the center of Seoul. Between 1990 and 1995, the area of major population growth has been within a belt at a distance between 10 and 30㎞ from the center of Seoul, while the area's population growth rate has slowed down between 1995 and 2000. On the other hand, the municipalities at a distance between 31-40㎞ showed a growth rate of 18.16 percent between 1990 and 1995, but they grew by 34.93 percent between 1995 and 2000.

Table IV-5. Population growth patterns in Gyeonggi Province, 1990-2000.

Distance from the center of Seoul (㎞)	No. of municipalities	Population (persons)			Growth rate (%)		
		1990	1995	2000	1990-1995	1995-2000	1990-2000
10~20	6	1,903,749	2,498,451	2,744,152	31.24	9.83	44.14
21~30	11	1,995,051	2,901,573	3,544,369	45.44	22.15	77.66
31~40	4	981,016	1,159,163	1,564,116	18.16	34.93	59.44
41~50	5	485,866	496,682	589,139	2.23	18.61	21.26
51~70	5	696,943	755,599	838,237	8.42	10.94	20.27

Large residential development projects have contributed to rapid population growth in Gyeonggi Province in the 1990s. As part of efforts to alleviate housing shortages in the Seoul Metropolitan Region, five new towns were developed during the period 1989-1996 to provide about 294,000 housing units. Table IV-6 provides an overview of five new town projects.

Table IV-6. Overview of five new towns in Gyeonggi Province.

Town	Location	Total area (㎢)	No. of housing units (thousand units)	Project period	Developer
Bundang	Seoungnam	19.6	97.5	1989-1996	Korea Land Corporation
Ilsan	Goyang	15.7	69.0	1989-1995	Korea Land Corporation
Pyeongchon	Anyang	5.1	42.5	1989-1995	Korea Land Corporation
Sanbon	Gunpo	4.2	42.5	1989-1995	Korea National Housing Corporation
Joongdong	Bucheon	5.4	42.5	1989-1995	Korea Land Corporation Korea National Housing Corporation Bucheon City

Seoul has faced a shortage of land where affordable housing can be built. The suburban areas such as Yongin, Paju, and Gimpo in Gyeonggi Province became a site for housing development due to its locational advantages. Thus, the rapid growth of suburban areas was closely associated with continuous housing development and has brought a lot of changes in the landscape of suburban areas. One of the typical examples was Yongin's rapid growth, which has been characterized by a leapfrog type of development, largely as a result of public and private residential development. Table IV-7 summarizes large housing development projects in Yongin. While public organizations such as Korea Land Corporation and Korea National Housing Corporation undertook large housing development projects, private sector developers participated in small housing development projects.

Table IV-7. Overview of large housing development projects in Yongin.

Project name	Project period	Total area (thousand ㎡)	No. of housing units	Developer
Guseong	1999-2006	994	5,695	Korea National Housing Corporation
Gimryang	1993-1998	59	882	Yongin City
Dongbaek	1997-2006	3,305	16,672	Korea Land Corporation
Dongcheon	1995-2003	213	1,874	Korea Land Corporation
Bora	1999-2006	819	4,516	Korea National Housing Corporation
Seocheon	2001-2007	1,171	4,161	Korea National Housing Corporation
Soozi	1989-1994	949	9,363	Korea Land Corporation
Soozi2	1993-2002	948	6,581	Korea Land Corporation
Shingal	1998-2005	412	3,533	Korea National Housing Corporation
Shinbong	1995-2004	446	2,873	Korea Land Corporation
Yeokbook	1993-1998	59	808	Yongin City
Jookjeon	1998-2006	3,592	18,479	Korea Land Corporation
Hweungdeok	2001-2008	2,146	9,180	Korea Land Corporation

Employment

Table IV-8 shows the profile of changes in both total and sectoral employment in Gyeonggi Province during the 1990-2000 period. Gyeonggi Province showed an increasing trend in total employment during the 1990-2000 period. Total employment increased 127.2 percent from 843,062 persons in 1990 to 1,915,746 in 2000. The total employment was disaggregated by nine major industrial sectors: Agricultural, Fishery & Forestry (AFF); Manufacturing & Mining (MM); Construction (CON); Wholesale & Retail Trade (WRT); Hotels & Restaurants (HR); Transportation, Communication & Public Utilities (TCP); Finance & Insurance (FI); Real Estate, Renting & Leasing (RRL); and Services (SER). Among nine sectors, all the sectors except the agricultural, fishery & forestry sector have grown continuously in Gyeonggi Province over the same period.

Whereas the manufacturing & mining sector held the largest portion of the total employment in Gyeonggi Province during the 1999-2000 period, its percentage decreased significantly over time. The services sector held the second largest portion of the total employment and its percentage continued to increase over the same period. Most notably, the wholesale & retail trade sector, the hotels & restaurants sector, and the real estate, renting & leasing sector increased greatly in Gyeonggi Province. In particular, the percentage of the wholesale & retail sector reached 11.7 in 2000. The hotels & restaurants sector showed the highest growth rate from 1990 to 2000. Overall, Gyeonggi Province's employment opportunities have improved during the 1990-2000 period. In particular, the tertiary industry played an important role in its economic base, which reflects economic restructuring in Gyeonggi Province.

Table IV-8. Total and sectoral employment changes in Gyeonggi Province, 1990-2000.

Sector		Employment (persons)			Percent distribution (%)			Change rate (%)		
		1990	1995	2000	1990	1995	2000	1990-1995	1995-2000	1990-2000
Gyeonggi Province	Total	843,062	1,016,087	1,915,746	100.00	100.00	100.00	20.52	88.54	127.24
	AFF	1,632	3,220	2,928	0.19	0.32	0.15	97.30	-9.07	79.41
	MM	682,745	694,759	832,650	80.98	68.38	43.46	1.76	19.85	21.96
	CON	16,699	46,536	77,254	1.98	4.58	4.03	178.68	66.01	362.63
	WRT	12,161	41,864	224,204	1.44	4.12	11.70	244.25	435.55	1743.63
	HR	4,634	7,257	170,625	0.55	0.71	8.91	56.60	2251.18	3582.02
	TCP	43,346	64,843	92,152	5.14	6.38	4.81	49.59	42.12	112.60
	FI	13,428	36,577	85,568	1.59	3.60	4.47	172.39	133.94	537.24
	RRL	3,457	25,471	55,907	0.41	2.51	2.92	636.79	119.49	1517.21
	SER	64,960	95,560	374,458	7.71	9.40	19.55	47.11	291.86	476.44

Note: The employment data are based on establishments with more than five workers.

Table IV-9 shows the profile of changes in both total and sectoral employment by zone in Gyeonggi Province during the 1990-2000 period. Overall, total employment continued to increase in each zone. The manufacturing & mining sector held the largest portion of the total employment in each zone during the 1999-2000 period, but its percentage decreased significantly over time. The services sector held the second largest portion of the total employment and its percentage continued to increase over the same period. The wholesale & retail trade sector and the hotels & restaurants sector showed high growth in employment in each zone.

Table IV-9. Total and sectoral employment changes by zone, 1990-2000.

Sector		Employment (persons)			Percent distribution (%)			Change rate (%)		
		1990	1995	2000	1990	1995	2000	1990-1995	1995-2000	1990-2000
Over-concentration control zone	Total	433,266	509,115	1,033,841	100	100	100	17.51	103.07	138.62
	AFF	193	421	473	0.04	0.08	0.05	118.13	12.35	145.08
	MM	326,354	308,121	351,668	75.32	60.52	34.02	-5.59	14.13	7.76
	CON	13,061	31,721	42,164	3.01	6.23	4.08	142.87	32.92	222.82
	WRT	9,347	26,845	149,199	2.16	5.27	14.43	187.20	455.78	1496.22
	HR	2,616	3,546	102,285	0.60	0.70	9.89	35.55	2784.52	3809.98
	TCP	27,917	40,088	60,481	6.44	7.87	5.85	43.60	50.87	116.65
	FI	10,708	22,161	55,729	2.47	4.35	5.39	106.96	151.47	420.44
	RRL	2,768	20,620	40,534	0.64	4.05	3.92	644.94	96.58	1364.38
	SER	40,302	55,592	231,308	9.30	10.92	22.37	37.94	316.08	473.94
Growth management zone	Total	349,282	426,729	757,872	100	100	100	22.17	77.60	116.98
	AF	873	2,144	2,050	0.25	0.50	0.27	145.59	-4.38	134.82
	MM	307,561	329,855	420,691	88.06	77.30	55.51	7.25	27.54	36.78
	CON	2,945	11,275	28,172	0.84	2.64	3.72	282.85	149.86	856.60
	WRT	2,325	12,495	63,625	0.67	2.93	8.40	437.42	409.20	2636.56
	HR	1,347	2,249	55,406	0.39	0.53	7.31	66.96	2363.58	4013.29
	TCP	11,256	19,123	27,126	3.22	4.48	3.58	69.89	41.85	140.99
	FI	2,131	11,129	24,610	0.61	2.61	3.25	422.24	121.13	1054.86
	RRL	488	4,576	13,893	0.14	1.07	1.83	837.70	203.61	2746.93
	SER	20,356	33,883	122,299	5.83	7.94	16.14	66.45	260.95	500.80
Nature preservation zone	Total	60,514	80,243	124,033	100	100	100	32.60	54.57	104.97
	AFF	566	655	405	0.94	0.82	0.33%	15.72	-38.17	-28.45
	MM	48,830	56,783	60,291	80.69	70.76	48.61%	16.29	6.18	23.47
	CON	693	3,540	6,918	1.15	4.41	5.58%	410.82	95.42	898.27
	WRT	489	2,524	11,380	0.81	3.15	9.17%	416.16	350.87	2227.20
	HR	671	1,462	12,934	1.11	1.82	10.43%	117.88	784.68	1827.57
	TCP	4,173	5,632	4,545	6.90	7.02	3.66%	34.96	-19.30	8.91
	FI	589	3,287	5,229	0.97	4.10	4.22%	458.06	59.08	787.78
	RRL	201	275	1,480	0.33	0.34	1.19%	36.82	438.18	636.32
	SER	4,302	6,085	20,851	7.11	7.58	16.81%	41.45	242.66	384.68

Note: The employment data are based on establishments with more than five workers.

Land Use

The process and pattern of urban growth and change has a significant effect on the form and function of cities. This section examines the overall change in land use pattern in Gyeonggi Province during the 1990-2000 period in order to identify the main sources in land use changes. Table IV-10 shows the overall change among the various land use categories in Gyeonggi Province during the 1990-2000 period. The extent of change in each category of land use varied over time.

Forestry accounted for more than fifty percent of Gyeonggi Province’s total area and its percentage decreased during the 1990-2000 period. Agricultural land held the second largest portion and its percentage also decreased over the same period. On the other hand, residential land continued to increase. This pattern resulted from the continued housing development in Gyeonggi Province during the 1990s. As stated before, Gyeonggi Province has served as a site for housing development to alleviate housing shortages in the Seoul Metropolitan Region. As a result, agricultural and forest lands have faced a variety of development pressures. The continued residential development has contributed to the loss of arable agricultural land and forestry in Gyeonggi Province. In particular, the deregulation in the national land use planning system in 1993, which eased the conversion of agricultural and forest lands to other uses, promoted residential development in Gyeonggi. Industrial, transportation, school, and park continued to increase during the 1990-2000 period.

Table IV-10. Overall land use change in Gyeonggi Province, 1990-2000.

Land use Category	Area (㎢)			Percent distribution (%)			Change rate (%)		
	1990	1995	2000	1990	1995	2000	1990-1995	1995-2000	1990-2000
Total	10,160.210	10,114.552	10,189.104	100.00	100.00	100.00	-0.45	0.74	0.28
Agricultural	2,825.785	2,727.730	2,619.824	27.81	26.97	25.71	-3.47	-3.96	-7.29
Forestry	5,846.359	5,790.653	5,702.387	57.54	57.25	55.97	-0.95	-1.52	-2.46
Residential	236.886	283.663	343.639	2.33	2.80	3.37	19.75	21.14	45.07
Industrial	41.202	64.941	94.210	0.41	0.64	0.93	57.61	45.07	128.65
Transportation	217.213	254.610	300.981	2.14	2.52	2.95	17.22	18.21	38.57
School	16.297	20.826	28.359	0.16	0.21	0.28	27.79	36.17	74.01
Park	2.458	9.069	17.259	0.02	0.09	0.17	268.96	90.32	602.20
Others	974.009	963.060	1,082.444	9.59	9.52	10.62	-1.12	12.40	11.13

Table IV-11 shows the spatial patterns of land use change by zone in Gyeonggi Province during the 1990-2000 period. The patterns of land use change varied among three zones. Agricultural land and forestry accounted for the largest portion of land in each zone. However, their portion was much higher in the growth management zone and the nature preservation zone than in the over-concentration control zone. While agricultural land and forestry decreased in each zone during the 1990-2000 period, residential use increased in each zone. In particular, agricultural land and forestry decreased greatly in the over-concentration control zone. On the other hand, the over-concentration control zone showed the highest rate of growth in residential use among three zones over the same period. The portion of residential use was the highest in the over-concentration control zone among three zones.

Industrial use increased 147.08 percent in the growth management zone and 118.85

percent in the nature preservation zone between 1990 and 2000, respectively, largely due to the restriction imposed on industrial use in the over-concentration control zone. School and park increased greatly in the over-concentration control zone. The over-concentration control zone also showed the highest growth rate in transportation during the 1990-2000 period.

Table IV-11. Land use change by zone in Gyeonggi Province, 1990-2000.

Land use category		Area (㎢)			Percent distribution (%)			Change rate (%)		
		1990	1995	2000	1990	1995	2000	1990-1995	1995-2000	1990-2000
Over-concentration control zone	Total	1,104.476	1,139.541	1,146.361	100.00	100.00	100.00	3.18	0.60	3.79
	Agricultural	323.355	299.704	264.805	29.28	26.30	23.10	-7.31	-11.64	-18.11
	Forestry	521.317	505.404	486.539	47.20	44.35	42.44	-3.05	-3.73	-6.67
	Residential	82.342	107.161	129.162	7.46	9.40	11.27	30.14	20.53	56.86
	Industrial	9.504	15.972	17.437	0.86	1.40	1.52	68.06	9.17	83.47
	Transportation	44.490	63.769	84.370	4.03	5.60	7.36	43.33	32.31	89.64
	School	4.627	7.730	12.275	0.42	0.68	1.07	67.06	58.79	165.26
	Park	1.382	6.562	13.595	0.13	0.58	1.19	374.74	107.18	883.57
	Others	117.458	133.239	138.179	10.64	11.69	12.05	13.44	3.71	17.64
Growth management zone	Total	5,832.108	5,751.529	5,819.990	100.00	100.00	100.00	-1.38	1.19	-0.21
	Agricultural	1,806.091	1,738.937	1,686.667	30.97	30.23	28.98	-3.72	-3.01	-6.61
	Forestry	3,119.817	3,089.598	3,038.809	53.49	53.72	52.21	-0.97	-1.64	-2.60
	Residential	116.484	134.099	160.871	2.00	2.33	2.76	15.12	19.96	38.11
	Industrial	26.221	40.450	64.787	0.45	0.70	1.11	54.27	60.16	147.08
	Transportation	122.508	135.947	154.318	2.10	2.36	2.65	10.97	13.51	25.97
	School	8.729	10.282	12.529	0.15	0.18	0.22	17.79	21.85	43.52
	Park	1.040	2.474	3.620	0.02	0.04	0.06	138.01	46.28	248.16
	Others	631.217	599.742	698.390	10.82	10.43	12.00	-4.99	16.45	10.64
Nature preservation zone	Total	3,223.626	3,223.481	3,222.753	100.00	100.00	100.00	0.00	-0.02	-0.03
	Agricultural	696.339	689.090	668.353	21.60	21.38	20.74	-1.04	-3.01	-4.02
	Forestry	2,205.225	2,195.650	2,177.039	68.41	68.11	67.55	-0.43	-0.85	-1.28
	Residential	38.060	42.402	53.606	1.18	1.32	1.66	11.41	26.42	40.85
	Industrial	5.477	8.518	11.987	0.17	0.26	0.37	55.53	40.71	118.85
	Transportation	50.215	54.895	62.294	1.56	1.70	1.93	9.32	13.48	24.05
	School	2.941	2.813	3.556	0.09	0.09	0.11	-4.32	26.38	20.92
	Park	0.036	0.032	0.044	0.00	0.00	0.00	-10.84	38.09	23.12
	Others	225.333	230.080	245.875	6.99	7.14	7.63	2.11	6.86	9.12

CHAPTER V

FINDINGS

5.1 Introduction

This chapter tests research hypotheses and reports the empirical findings. The following five sections test research hypotheses using the method and procedure of analysis presented in Chapter III. Data analysis was carried out based upon sustainability index scores for 31 study areas in 1990, 1995, and 2000. Table V-1 lists the sustainability index scores for 31 study areas which were calculated according to the method and procedure presented in Chapter III. The statistical analysis was conducted using SPSS 12.0 statistical software.

Table V-1. Sustainability index scores, 1990-2000.

Area	1990	1995	2000	Area	1990	1995	2000
Ansan	-13.41962	-9.28141	-11.30802	Namyangju	-6.80056	-7.53916	-5.97964
Anseong	5.02482	11.59048	8.86007	Osan	7.28737	4.13796	-3.87958
Anyang	-5.41408	-0.53435	1.97417	Paju	5.78040	-0.91785	0.69431
Bucheon	-9.59608	-6.99471	-6.12536	Pocheon	9.48109	1.18035	-9.16319
Dongducheon	-4.86337	-7.07532	-2.78105	Pyeongtaek	0.95992	0.24528	0.93225
Gapyeong	16.71061	9.38384	9.03126	Seongnam	-0.77176	-1.18519	2.30437
Gimpo	2.81367	-0.13996	-5.40419	Siheung	-8.83247	-0.86316	-8.92379
Goyang	-4.97280	-4.78696	3.50538	Suwon	-0.02976	-0.29969	4.44113
Gunpo	-12.28072	-3.68841	5.59761	Uijeongbu	2.02793	-2.71812	2.75161
Guri	-8.03478	-8.59088	-3.90710	Uiwang	-1.24995	3.59019	4.77095
Gwacheon	6.54961	-1.00094	0.55878	Yangju	-7.09903	-10.77725	-14.81050
Gwangju	-5.35774	-9.25214	-9.05714	Yangpyeong	12.22455	17.60455	13.25257
Gwangmyeong	-9.50094	0.88981	7.14065	Yeoju	14.22604	15.33061	13.44242
Hanam	-7.22367	-3.90325	-4.50059	Yeoncheon	7.41837	4.15991	5.52635
Hwaseong	0.32405	4.36526	-2.57695	Yongin	2.50442	-0.97143	-6.10703
Icheon	12.11441	8.04186	9.74033				

5.2 Hypothesis 1

The first hypothesis to be tested is:

The level of urban sustainability tends to be higher in more densely populated areas than in less densely populated areas within a region.

This hypothesis aims to examine whether there is a difference in the level of urban sustainability among the study areas with different population densities for the years 1990, 1995 and 2000. To test this hypothesis, this study divides 31 study areas into four groups according to their population densities. Group 1 is the areas with the highest population densities and Group 4 is the areas with the lowest population densities. Each population density group has eight study areas except Group 4 (seven study areas). The analysis of variance (ANOVA) tests were conducted to examine the differences in the level of sustainability among different groups of population densities.

5.2.1 1990

Table V-2 presents the number of areas, means, and standard deviations for the ANOVA test by population density group. As indicated in Table V-3, the result of the ANOVA test showed that the differences in the means for the level of sustainability among four population density groups were statistically significant at the 0.05 level ($p < 0.05$). Specifically, the result of performing multiple comparisons by Scheffe's method among four population density groups, the mean differences between Group1 and Group 4, and between Group 2 and Group 4 were significant, respectively (see Table V-4).

Table V-2. Descriptive statistics of sustainability by population density group, 1990.

Group	Number of areas	Population density (persons/㎢)	Sustainability score	
			Mean	Std. Deviation
1	8	3372-12800	-7.3809675	4.95539962
2	8	750-2596	-1.4096688	6.14533205
3	8	256-620	1.3246600	6.30185140
4	7	60-214	8.5325343	7.30653599

Table V-3. ANOVA test: sustainability among population density groups, 1990.

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	975.394	3	325.131	8.485	.000
Within Groups	1034.554	27	38.317		
Total	2009.947	30			

Table V-4. Multiple comparisons: sustainability among population density groups, 1990.

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.
1	2	-5.97129875	3.09502852	.314
	3	-8.70562750	3.09502852	.070
	4	-15.91350179(*)	3.20365888	.000
2	1	5.97129875	3.09502852	.314
	3	-2.73432875	3.09502852	.853
	4	-9.94220304(*)	3.20365888	.039
3	1	8.70562750	3.09502852	.070
	2	2.73432875	3.09502852	.853
	4	-7.20787429	3.20365888	.193
4	1	15.91350179(*)	3.20365888	.000
	2	9.94220304(*)	3.20365888	.039
	3	7.20787429	3.20365888	.193

* The mean difference is significant at the .05 level.

5.2.2 1995

Table V-5 shows the number of areas, means, and standard deviations for four population density groups. The result of the ANOVA test showed that the means for the level of sustainability among four population density groups were significantly different at the 0.05 level ($p < 0.05$) (see Table V-6). Multiple comparisons by Scheffe's method among four population density groups showed that the mean difference between Group1 and Group 4 was significant (see Table V-7).

Table V-5. Descriptive statistics of sustainability by population density group, 1995.

Group	Number of areas	Population density (persons/㎢)	Sustainability score	
			Mean	Std. Deviation
1	8	3510-14619	-3.7106038	4.05147710
2	8	762-3438	-1.5774500	3.91792568
3	8	239-737	-.9616563	5.99026200
4	7	65-225	7.1425143	9.26044512

Table V-6. ANOVA test: sustainability among population density groups, 1995.

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	494.562	3	164.854	4.505	.011
Within Groups	988.070	27	36.595		
Total	1482.632	30			

Table V-7. Multiple comparisons: sustainability among population density groups, 1995.

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.
1	2	-2.13315375	3.02469771	.918
	3	-2.74894750	3.02469771	.843
	4	-10.85311804(*)	3.13085958	.018
2	1	2.13315375	3.02469771	.918
	3	-.61579375	3.02469771	.998
	4	-8.71996429	3.13085958	.074
3	1	2.74894750	3.02469771	.843
	2	.61579375	3.02469771	.998
	4	-8.10417054	3.13085958	.107
4	1	10.85311804(*)	3.13085958	.018
	2	8.71996429	3.13085958	.074
	3	8.10417054	3.13085958	.107

* The mean difference is significant at the .05 level.

5.2.3 2000

Table V-8 presents the number of areas, means, and standard deviations for four population density groups in 2000. As indicated in Table V-9, the result of the ANOVA test showed that there was a significant difference in the means for the level of sustainability among the groups with different population densities at the 0.05 level ($p < 0.05$). Multiple comparisons by Scheffe's method among four population density groups showed that the mean difference between Group3 and Group 4 was significant (see Table V-10).

Table V-8. Descriptive statistics of sustainability by population density group, 2000.

Group	Number of areas	Population density (persons/㎢)	Sustainability score	
			Mean	Std. Deviation
1	8	4443-14596	1.7721350	4.57456239
2	8	802-3972	-2.8197400	5.63535337
3	8	284-794	-4.1578588	7.24787013
4	7	67-284	5.9491129	7.99621598

Table V-9. ANOVA test: sustainability among population density groups, 2000.

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	474.777	3	158.259	3.815	.021
Within Groups	1120.145	27	41.487		
Total	1594.922	30			

Table V-10. Multiple comparisons: sustainability among population density groups, 2000.

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.
1	2	4.59187500	3.22051435	.573
	3	5.92999375	3.22051435	.354
	4	-4.17697786	3.33354906	.670
2	1	-4.59187500	3.22051435	.573
	3	1.33811875	3.22051435	.981
	4	-8.76885286	3.33354906	.099
3	1	-5.92999375	3.22051435	.354
	2	-1.33811875	3.22051435	.981
	4	-10.10697161(*)	3.33354906	.045
4	1	4.17697786	3.33354906	.670
	2	8.76885286	3.33354906	.099
	3	10.10697161(*)	3.33354906	.045

* The mean difference is significant at the .05 level.

5.2.4 Summary

Figure V-1 summarizes the mean levels of sustainability in four population density groups during the 1990-2000 period. The results of the ANOVA tests showed that there were significant differences in the means for the level of sustainability among four population density groups. Specifically, there were significant differences in the means between Group1 and Group 4, and between Group 2 and Group 4 in 1990. The mean difference between Group1 and Group 4 was significant in 1995. In 2000, there was a significant difference in the means between Group3 and Group 4. The common thing these groups showed is that the groups with higher densities showed the lower mean values of sustainability. This result indicates that the level of urban sustainability is not higher in more densely populated areas than in less densely populated areas in the Seoul Metropolitan Region. As a result, Hypothesis 1 was not supported.

According to the compact city model, it is said that compact urban development, which is characterized by high-density residential living, is sustainable. However, this study found that the study areas with higher densities showed the lower levels of sustainability. These results indicate that increased density does not necessarily result in improved sustainability.

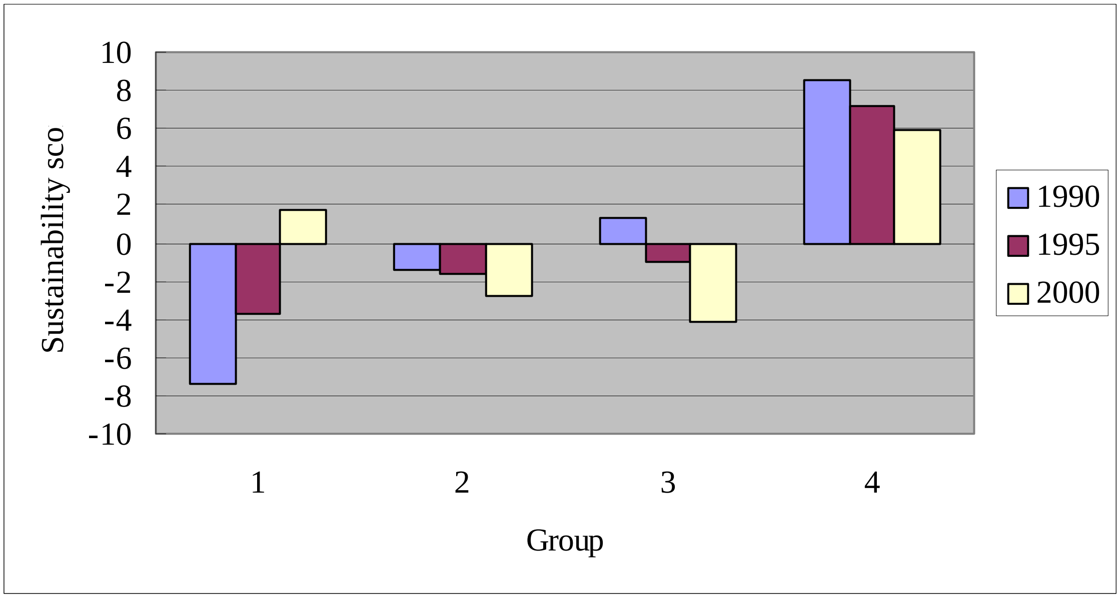

Figure V-1. Mean level of sustainability among population density groups, 1990-2000.

5.3 Hypothesis 2

The second hypothesis to be tested is:

The trend of sustainability in urban areas with green belt tends to be stable over time, however, the trend of sustainability in their surrounding areas tends to decrease over time.

This hypothesis aims to examine the relationship between cities' growth limitation measure and its impact on sustainability of the cities and their surrounding areas. This study attempts to compare the change in the level of sustainability in urban areas with green belt and their surrounding areas over time by conducting paired t-tests of the difference in the level of sustainability.

5.3.1 Urban Areas with Green Belt

Table V-11 presents the results of paired t-tests for the means of the level of

sustainability in seven urban areas where green belt accounts for more than 70 percent of the total land area: Guri, Gwacheon, Gwangmyeong, Hanam, Siheung, Uijeongbu, and Uiwang. These areas showed an increasing trend toward sustainability over time. However, the results of paired t-tests showed that the differences in the means of the level of sustainability were not statistically significant at the 0.05 level during the 1990-2000 period ($p > 0.05$). These results imply that the level of sustainability has not improved significantly in urban areas with green belt over the same period.

Table V-11. Paired t-tests for urban areas with green belt, 1990-2000.

Year	Mean	Number of areas	Paired Differences		t	Df	Sig. (2-tailed)
			Mean	Std. Deviation			
1990 1995	-3.7520386 -1.7994786	7 7	-1.95256000	6.57124216	-.786	6	.462
1995 2000	-1.7994786 -.3013557	7 7	-1.49812286	4.90536491	-.808	6	.450

5.3.2 Surrounding Areas

Table V-12 presents the results of paired t-tests for the means of the level of sustainability in eight surrounding areas during the 1990-2000 period: Ansan, Gimpo, Hwaseong, Namyangju, Osan, Paju, Yangju, and Yongin. These areas showed a decreasing trend toward sustainability over time. The results of paired t-tests showed that the difference in the means of the level of sustainability between 1990 and 1995 was not statistically significant ($p > 0.05$), but the difference in the means between 1995 and 2000 was significant at the 0.05 level ($p < 0.05$). These results indicate that the level of sustainability in surrounding areas has not deteriorated significantly during the 1990-1995 period, but has deteriorated significantly during the 1995-2000 period.

Table V-12. Paired t-tests for surrounding areas, 1990-2000.

Year	Mean	Number of areas	Paired Differences		t	Df	Sig. (2-tailed)
			Mean	Std. Deviation			
1990 1995	-1.0761625 -2.6404800	8 8	1.56431750	3.84605695	1.150	7	.288
1995 2000	-2.6404800 -6.1714500	8 8	3.53097000	3.62974134	2.751	7	.028

5.3.3 Summary

Figure V-2 summarizes the mean levels of sustainability in urban areas with green belt and their surrounding areas during the 1990-2000 period. The two subject areas showed different trends towards sustainability. The level of sustainability has increased in urban areas with green belt over time, but the mean differences were not statistically significant during the 1990-2000 period. On the contrary, the level of sustainability has declined in their surrounding areas over time. In particular, the results of paired t-tests showed that there was a significant decline between 1995 and 2000. These results imply the possibility that whereas a growth control measure such as green belt may not be able to make a significant contribution to achieving sustainability in urban areas, it could have a negative effect on sustainability in their surrounding areas by creating side effects such as a leapfrog urban development in areas beyond the green belt's outer boundary.

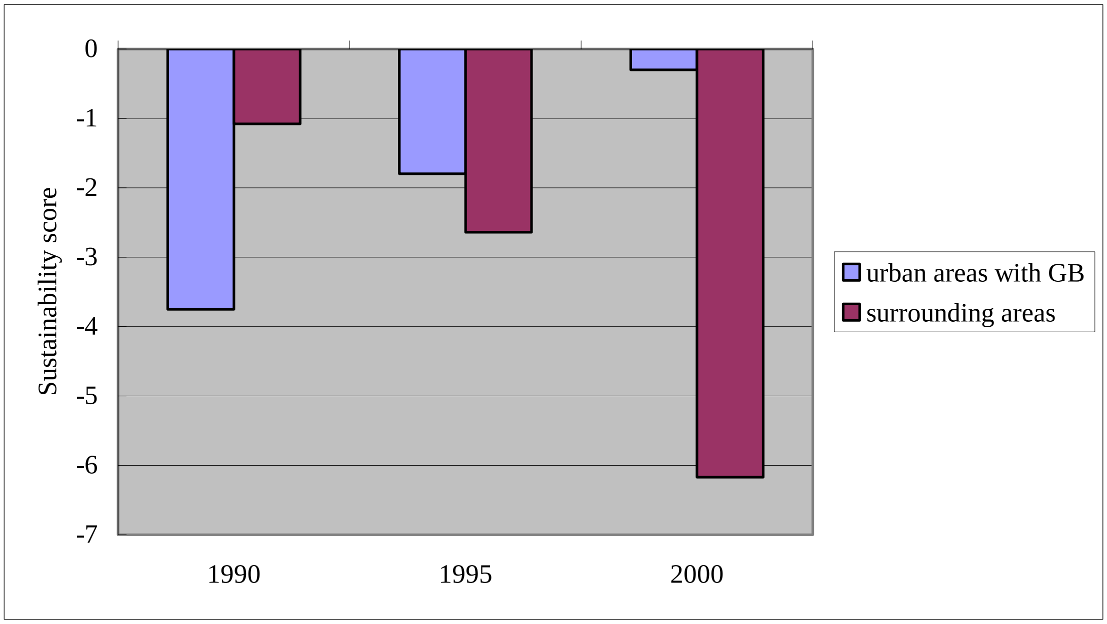

Figure V-2. Mean level of sustainability in urban areas with green belt and their surrounding areas, 1990-2000.

5.4 Hypothesis 3

The third hypothesis to be tested is:

The degree of sustainability of a region becomes greater over time.

This hypothesis aims to examine the pattern of change in the level of sustainability of a region over time. This study attempts to compare the change in the level of sustainability in both the entire region and its three sub-regions over time (over-concentration control zone, growth management zone, and nature preservation zone) using paired t-tests.

5.4.1 The Entire Region

Table V-13 presents the results of paired t-tests for the means of the level of

sustainability for the entire region (31 study areas in Gyeonggi Province). The results showed that there were no significant differences in the means of the level of sustainability between 1990 and 1995, and between 1995 and 2000 at the 0.05 level, respectively ($p > 0.05$). These results indicate that the overall level of sustainability in the entire region has not improved during the 1990-2000 period.

Table V-13. Paired t-tests for the entire region, 1990-2000.

Year	Mean	Number of areas	Paired Differences		t	Df	Sig. (2-tailed)
			Mean	Std. Deviation			
1990 1995	-.0000023 -.0000026	31 31	.00000032	5.02397847	.000	30	1.000
1995 2000	-.0000026 .0000026	31 31	-.00000516	4.86320617	.000	30	1.000

5.4.2 The Three Sub-regions

Over-concentration Control Zone

Table V-14 shows the results of paired t-tests for the means of the level of sustainability in the over-concentration control zone. Overall, the zone showed an increasing trend toward sustainability over time. The results of paired t-tests showed that the difference in the means of the level of sustainability between 1990 and 1995 was not statistically significant ($p > 0.05$), but the difference in the means between 1995 and 2000 was significant at the 0.05 level ($p < 0.05$). These results imply that the sustainability in the over-concentration control zone has not improved significantly during the 1990-1995 period, but has improved significantly during the 1995-2000 period.

Table V-14. Paired t-tests for the over-concentration control zone, 1990-2000.

Year	Mean	Number of areas	Paired Differences		t	Df	Sig. (2-tailed)
			Mean	Std. Deviation			
1990 1995	-4.56381 -2.31428	13 13	-2.24952385	5.20156332	-1.559	12	.145
1995 2000	-2.31428 .7375238	13 13	-3.05180538	4.43193374	-2.483	12	.029

Growth Management Zone

Table V-15 presents the results of paired t-tests for the means of the level of sustainability in the growth management zone. Overall, the zone showed a decreasing trend toward sustainability over time. The results of paired t-tests showed that the difference in the means of the level of sustainability between 1990 and 1995 was not statistically significant ($p > 0.05$), but the difference in the means between 1995 and 2000 was significant at the 0.05 level ($p < 0.05$). These results indicate that the sustainability in the growth management zone has deteriorated significantly during the 1995-2000 period.

Table V-15. Paired t-tests for the growth management zone, 1990-2000.

Year	Mean	Number of areas	Paired Differences		t	Df	Sig. (2-tailed)
			Mean	Std. Deviation			
1990 1995	.7239638 -.8479338	13 13	1.57189769	4.27231156	1.327	12	.209
1995 2000	-.8479338 -3.53824	13 13	2.69031000	4.40737984	2.201	12	.048

Nature Preservation Zone

Table V-16 presents the results of paired t-tests for the means of the level of

sustainability in the nature preservation zone. The results of paired t-tests showed that there were no significant differences in the means of the level of sustainability between 1990 and 1995, and between 1995 and 2000 at the 0.05 level, respectively ($p > 0.05$). These results imply that the level of sustainability in this zone has not changed significantly during the 1990-2000 period.

Table V-16. Paired t-tests for the nature preservation zone, 1990-2000.

Year	Mean	Number of areas	Paired Differences		t	Df	Sig. (2-tailed)
			Mean	Std. Deviation			
1990 1995	9.9835740 8.2217440	5 5	1.76183000	5.00194521	.788	4	.475
1995 2000	8.2217440 7.2818880	5 5	.93985600	2.29866716	.914	4	.412

5.4.3 Summary

For the entire region, the overall level of sustainability has not improved over the 1990-2000 period. However, different trends of sustainability have emerged within different parts of the region over the same period. Figure V-3 summarizes the mean levels of sustainability across the three zones with different patterns of growth and change over the 1990-2000 period. The sustainability in the over-concentration control zone has improved over time. In particular, the results of paired t-tests showed that there was a significant improvement between 1995 and 2000. For the growth management zone, the sustainability continued to deteriorate over time. The results of paired t-tests showed that the sustainability in this zone has deteriorated significantly between 1995 and 2000. The level of sustainability in the nature preservation zone has decreased over time. But there were no significant differences among mean levels of sustainability during the 1990-2000 period.

As stated in Chapter IV, while the population growth rate has slowed down in the over-concentration control zone over time, the growth rate has increased in the growth management zone over time. The results of analysis imply the possibility that rapid urban growth and change has a negative effect on achieving sustainability and thus rapidly growing areas face serious sustainability challenges. In this respect, planners and policy makers in rapidly growing areas should take into account the fact that the pattern of urban growth and change may serve as a critical determinant influencing sustainability.

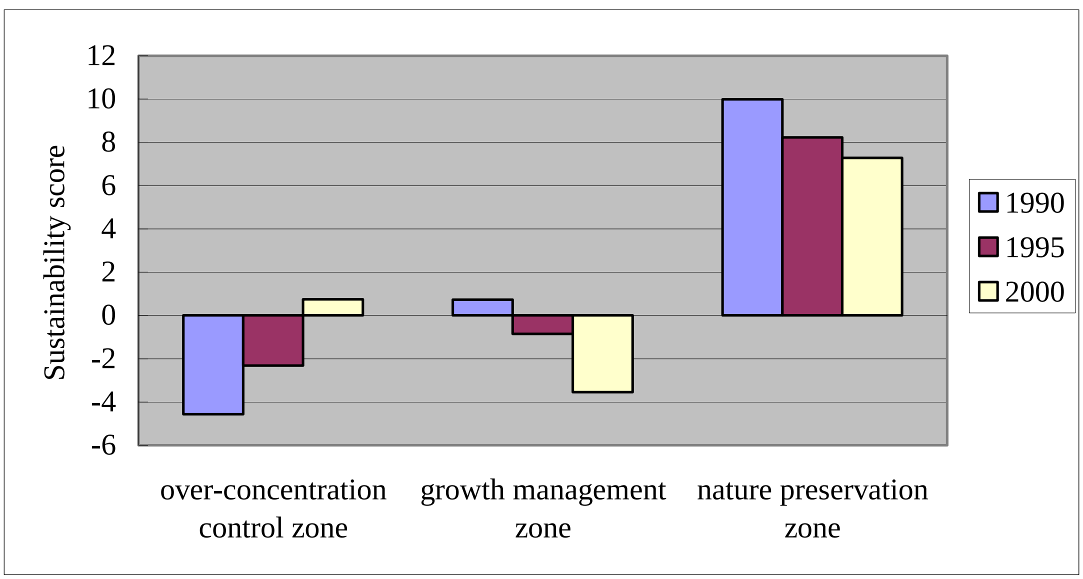

Figure V-3. Mean level of sustainability among three zones, 1990-2000.

5.5 Hypothesis 4

The fourth hypothesis to be tested is:

Different patterns of sustainability tend to emerge within different parts of a region. That is, the locational patterns of sustainability within a region tend to differ according to the patterns of growth and change in its sub-regions.

This hypothesis aims to examine the difference in the patterns of sustainability in different parts of the region. This study attempts to compare the patterns of sustainability in the three sub-regions with different urban growth patterns (over-concentration control zone, growth management zone, nature preservation zone) by performing ANOVA tests.

5.5.1 1990

Table V-17 presents the number of areas, means, and standard deviations for the ANOVA test by zone. As indicated in Table V-18, the result of the ANOVA test showed that the means for the level of sustainability among three zones were statistically significant at the 0.05 level ($p < 0.05$). Specifically, as a result of performing multiple comparisons by Scheffe's method among three zones, the mean differences between zone 1 and zone 2, and between zone 2 and zone 3 were significant, respectively (see Table V-19).

Table V-17. Descriptive statistics of sustainability by zone, 1990.

Zone*	Number of areas	Sustainability score	
		Mean	Std. Deviation
1	13	.7239638	6.86461337
2	5	9.9835740	8.77738403
3	13	-4.5638054	5.47997820
Total	31	-.00000230	8.18524552

* 1: growth management zone, 2: nature preservation zone, 3: over-concentration control zone.

Table V-18. ANOVA test: sustainability among three zones, 1990.

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	775.941	2	387.970	8.803	.001
Within Groups	1234.007	28	44.072		
Total	2009.947	30			

Table V-19. Multiple comparisons: sustainability among three zones, 1990.

(I) Zone	(J) Zone	Mean Difference (I-J)	Std. Error	Sig.
1	2	-9.25961015(*)	3.49348866	.044
	3	5.28776923	2.60389271	.146
2	1	9.25961015(*)	3.49348866	.044
	3	14.54737938(*)	3.49348866	.001
3	1	-5.28776923	2.60389271	.146
	2	-14.54737938(*)	3.49348866	.001

* The mean difference is significant at the .05 level.

5.5.2 1995

Table V-20 presents the number of areas, means, and standard deviations for three zones in 1995. The result of the ANOVA test showed that the means for the level of sustainability among three zones were statistically significant at the 0.05 level ($p < 0.05$) (see Table V-21). Multiple comparisons by Scheffe's method among three zones showed that the mean differences between zone 1 and zone 2, and between zone 2 and zone 3 were significant, respectively (see Table V-22).

Table V-20. Descriptive statistics of sustainability by zone, 1995.

Zone*	Number of areas	Sustainability score	
		Mean	Std. Deviation
1	13	-.8479338	6.39613992
2	5	8.2217440	10.55097711
3	13	-2.3142815	3.28447817
Total	31	-.0000026	7.03001246

* 1: growth management zone, 2: nature preservation zone, 3: over-concentration control zone.

Table V-21. ANOVA test: sustainability among three zones, 1995.

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	416.959	2	208.479	5.478	.010
Within Groups	1065.673	28	38.060		
Total	1482.632	30			

Table V-22. Multiple comparisons: sustainability among three zones, 1995.

(I) Zone	(J) Zone	Mean Difference (I-J)	Std. Error	Sig.
1	2	-9.06967785(*)	3.24647903	.032
	3	1.46634769	2.41978260	.833
2	1	9.06967785(*)	3.24647903	.032
	3	10.53602554(*)	3.24647903	.011
3	1	-1.46634769	2.41978260	.833
	2	-10.53602554(*)	3.24647903	.011

* The mean difference is significant at the .05 level.

5.5.3 2000

Table V-23 provides the number of areas, means, and standard deviations for three zones in 2000. The result of the ANOVA test showed that there was a significant difference in the means among three zones at the 0.05 level ($p < 0.05$) (see Table V-24). As shown in Table V-25, as a result of performing multiple comparisons by Scheffe's method among three zones, the mean difference between zone 1 and zone 2 was significant.

Table V-23. Descriptive statistics of sustainability by zone, 2000.

Zone*	Number of areas	Sustainability score	
		Mean	Std. Deviation
1	13	-3.5382438	6.52247937
2	5	7.2818880	9.34972290
3	13	.7375238	4.99824999
Total	31	.0000026	7.29136947

* 1: growth management zone, 2: nature preservation zone, 3: over-concentration control zone.

Table V-24. ANOVA test: sustainability among three zones, 2000.

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	434.950	2	217.475	5.250	.012
Within Groups	1159.972	28	41.428		
Total	1594.922	30			

Table V-25. Multiple comparisons: sustainability among three zones, 2000.

(I) Zone	(J) Zone	Mean Difference (I-J)	Std. Error	Sig.
1	2	-10.82013185(*)	3.38707131	.013
	3	-4.27576769	2.52457390	.255
2	1	10.82013185(*)	3.38707131	.013
	3	6.54436415	3.38707131	.173
3	1	4.27576769	2.52457390	.255
	2	-6.54436415	3.38707131	.173

* The mean difference is significant at the .05 level.

5.5.4 Summary

Figure V-4 summarizes the mean levels of sustainability by zone over the 1990-2000 period. The results of the ANOVA tests showed that there were significant differences in the means for the level of sustainability among three zones. Specifically, there were significant differences in the means between zone 1 and zone 2, and between zone 2 and zone 3 in 1990 and 1995. In 2000, there was a significant difference in the means between zone 1 and zone 2. Overall, the level of sustainability was much higher in zone 2 (nature preservation zone) than in zone 1 (growth management zone) and zone 3 (over-concentration control zone) during the 1990-2000 period. As stated before, while rapid growth of population has not occurred and land development has been strictly controlled in zone 2 during the period 1990-2000, there has been rapid population growth in zone 1 and zone 3. The results of analysis showed that there was no significant difference between zone 1 and zone 3.

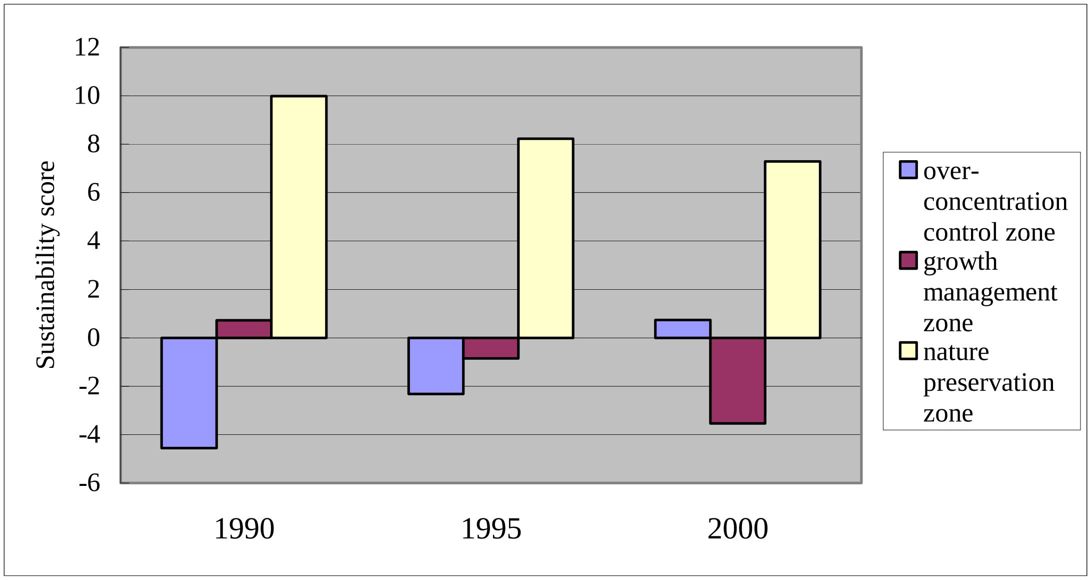

Figure V-4. Mean level of sustainability among three zones, 1990-2000.

5.6 Hypothesis 5

The fifth hypothesis to be tested is:

Key factors affecting the pattern of sustainability within a region tend to change over time.

Hypothesis 5 attempts to identify the key drivers influencing the pattern of sustainability in the region during the 1990-2000 period. In order to examine the changes in the underlying structure of elements affecting sustainability, this study conducts factor analysis of the dataset based on 38 variables (indicators) for 31 study areas in 1990, 1995, and 2000 (see Table V-26).

Table V-26. List of variables for factor analysis.

Category	Variable	Indicator
Population and Household	X1	Population growth rate
	X2	Population density
	X3	Average household size
	X4	Percentage of single-parent households
Land Use	X5	Percentage of agricultural area
	X6	Percentage of forest area
	X7	Percentage of greenbelt area
	X8	Public park acreage per capita
Transportation	X9	Car ownership rate
	X10	Percentage of commuters who walk or use bicycles
	X11	Percentage of commuters who use cars
	X12	Time spent commuting
Safety and Health	X13	Number of crimes per 1,000 inhabitants
	X14	Number of fires per 10,000 inhabitants
	X15	Percentage of population with access to safe drinking water
	X16	Access to sewage disposal facilities
	X17	Availability of medical services per 1,000 inhabitants
Housing and Education	X18	Number of housing units per 100 households
	X19	Home ownership rate
	X20	Level of educational attainment
	X21	Number of students per teacher
	X22	Number of students per classroom
Environment	X23	Waste generation per capita
	X24	Waste recycling rate
	X25	Water consumption per capita
	X26	Energy consumption per household
	X27	Number of air pollution facilities per 10,000 inhabitants
	X28	Number of water pollution facilities per 10,000 inhabitants
	X29	Use of chemical fertilizers
Economy	X30	Gross regional domestic product per capita
	X31	Number of people living in poverty per 1,000 inhabitants
	X32	Women’s job opportunity
	X33	Employment density
	X34	Employment diversification
	X35	Economic self-sufficiency
Community Engagement	X36	Number of NGOs per 10,000 inhabitants
	X37	Voter participation rate
	X38	Annual library visits per capita

5.6.1 1990

Table V-27 lists the eigenvalues associated with each factor. The eigenvalues associated with each factor represent the variance explained by that particular factor. As stated in Chapter III, the SPSS default is to select and rotate any factor with an eigenvalue greater than 1. As shown in Table V-27, the factor analysis of 38 variables for 31 study areas in 1990 extracted eight factors that account for 84.63 percent of total variance. Table V-27 also gives the factor loadings for the eight factors extracted. It lists the factor loadings that are higher than 0.5 or lower than –0.5 to avoid redundancy. The rotated factor matrix is a matrix of the factor loadings for each variable onto each factor. A factor loading is a measure of the contribution a variable makes to a particular factor.

Factor 1 accounts for 29.24 percent of total variance, and the loadings are positively strong (above 0.50) for X1, X2, X3, X10, X11, X12, X18, X19, X21, X22, X32, X35, and X37, and negatively strong (below –0.50) for X7, X15, X20, X31, and X33.

Factor 2 accounts for 11.35 percent of total variance. X9, X26, X27, and X28 show positively strong loadings, and X30 shows a negatively strong loading. Factor 3 accounts for 10.14 percent of total variance, and the loadings are positively strong for X20, X34, and X38, and negatively strong for X9 and X11.

For factor 4, X13 and X23 show positively strong loadings, and X16 shows a negatively strong loading. The loadings for factor 5 are positively strong for X5 and negatively strong for X6. For factor 6, X17 and X24 show positively strong loadings. The loadings for factor 7 are positively strong for X25 and negatively strong for X8. For factor 8, the loadings are positively strong for X4 and X29.

Table V-27. Rotated factor loadings and eigenvalues, 1990.

Variable	Factor							
	1	2	3	4	5	6	7	8
X1	.654							
X2	.572							
X3	.584							
X4								.881
X5					.889			
X6					-.821			
X7	-.823							
X8							-.795	
X9		.552	-.646					
X10	.778							
X11	.568		-.736					
X12	.834							
X13				.658				
X14								
X15	-.693							
X16				-.519				
X17						.817		
X18	.725							
X19	.765							
X20	-.511		.799					
X21	.884							
X22	.839							
X23				.828				
X24						.689		
X25							.605	
X26		.850						
X27		.873						
X28		.764						
X29								.692
X30		-.746						
X31	-.804							
X32	.688							
X33	-.897							
X34			.651					
X35	.871							
X36								
X37	.831							
X38			.925					
Eigenvalue	11.110	4.315	3.853	2.662	2.636	2.614	2.553	2.418
Percent of Variance	29.236	11.354	10.138	7.004	6.936	6.878	6.717	6.363
							Total = 84.627%	

5.6.2 1995

Table V-28 lists the eigenvalues associated with each factor and rotated factor loadings for 1995. The factor analysis of 38 variables for 31 study areas in 1995 extracted nine factors that account for 86.26 percent of total variance.

Factor 1 accounts for 31.86 percent of total variance. X1, X3, X10, X11, X12, X18, X19, X21, X22, X32, X35, and X37 show positively strong loadings, and X7, X8, X15, X16, X20, and X31 show negatively strong loadings.

Factor 2 accounts for 11.66 percent of total variance, and the loadings are positively strong for X9, X14, X27, and X28, and negatively strong for X2 and X36. Factor 3 accounts for 9.69 percent of total variance, and the loadings are positively strong for X26 and X34, and negatively strong for X30 and X33.

For factor 4, X38 shows a positively strong loading, and X13 shows a negatively strong loading. The loadings for factor 5 are positively strong for X4 and X23, and negatively strong for X17. For factor 6, X5 shows a positively strong loading, and X6 and X29 show negatively strong loadings. X18 and X37 show positively strong loadings for factor 7. The loading for factor 8 is positively strong for X25 and the loading for factor 9 is positively strong for X24.

Table V-28. Rotated factor loadings and eigenvalues, 1995.

Variable	Factor								
	1	2	3	4	5	6	7	8	9
X1	.630								
X2		-.509							
X3	.730								
X4					.595				
X5						.812			
X6						-.736			
X7	-.694								
X8	-.640								
X9		.602							
X10	.926								
X11	.884								
X12	.883								
X13				-.857					
X14		.795							
X15	-.847								
X16	-.627								
X17					-.552				
X18	.635						.628		
X19	.882								
X20	-.697								
X21	.895								
X22	.842								
X23					.824				
X24									.945
X25								.861	
X26			.858						
X27		.768							
X28		.731							
X29						-.573			
X30			-.869						
X31	-.829								
X32	.849								
X33			-.543						
X34			.733						
X35	.816								
X36		-.608							
X37	.564						.650		
X38				.836					
Eigenvalue	12.106	4.432	3.684	2.768	2.501	2.171	1.924	1.649	1.545
Percent of Variance	31.857	11.664	9.694	7.283	6.580	5.714	5.063	4.340	4.065
								Total = 86.261%	

5.6.3 2000

Table V-29 lists the eigenvalues associated with each factor and rotated factor loadings for 2000. The factor analysis of 38 variables for 31 study areas in 2000 extracted nine factors that account for 85.45 percent of total variance.

Factor 1 accounts for 25.89 percent of total variance, and the loadings are positively strong for X2, X10, X12, X18, X21, X22, X32, X35, and X37, and negatively strong for X7, X14, X15, X16, X20, and X31.

Factor 2 accounts for 10.97 percent of total variance. X14, X27, X28, and X34 show positively strong loadings. Factor 3 accounts for 10.59 percent of total variance, and the loadings are positively strong for X1, X11, and X26.

For factor 4, X38 shows a positively strong loading, and X13, X19, and X23 show negatively strong loadings. The loadings for factor 5 are positively strong for X5, X30, and X33, and negatively strong for X26. For factor 6, the loadings are positively strong for X23, X29 and negatively strong for X17. For factor 7, X8 shows a positively strong loading, and X36 shows a negatively strong loading. The loadings for factor 8 are positively strong for X3 and X25, and the loading for factor 9 is positively strong for X24.

Table V-29. Rotated factor loadings and eigenvalues, 2000.

Variable	Factor 1	2	3	4	5	6	7	8	9
X1			.827						
X2	.593								
X3								.666	
X4									
X5					.513				
X6									
X7	-.793								
X8							.765		
X9									
X10	.853								
X11			.895						
X12	.894								
X13				-.717					
X14	-.526	.745							
X15	-.720								
X16	-.567								
X17						-.689			
X18	.611								
X19				-.607					
X20	-.596								
X21	.894								
X22	.876								
X23				-.618		.516			
X24									.843
X25								.888	
X26			.567		-.529				
X27		.900							
X28		.792							
X29						.747			
X30					.767				
X31	-.746								
X32	.684								
X33					.781				
X34		.641							
X35	.859								
X36							-.561		
X37	.621								
X38				.880					
Eigenvalue	9.836	4.170	4.025	3.158	3.050	2.501	2.027	1.852	1.851
Percent of Variance	25.885	10.974	10.592	8.311	8.027	6.580	5.335	4.872	4.871
								Total = 85.449%	

5.6.4 Summary

Table V-30 summarizes the key variables comprising each factor based upon factor loadings. Overall, the first two factors, which cover about 40 percent of total variance, are assumed to play a key role in explaining the structural features of elements affecting the pattern of sustainability in the region during the 1990-2000 period. Specifically, although there were changes in eigenvalues and new factors emerged over time, population dimensions (X1: population growth rate, X2: population density, X3: average household size), transportation dimensions (X10: percentage of commuters who walk or use bicycles, X11: percentage of commuters who use cars, X12: time spent commuting), and health dimensions (X15: percentage of population with access to safe drinking water, X16: access to sewage disposal facilities) continued to serve as influential elements affecting the pattern of sustainability in the region during the study period.

Housing and education dimensions (X18: number of housing units per 100 households, X19: home ownership rate, X20: level of educational attainment, X21: number of students per teacher, X22: number of students per classroom), environment dimensions (X27: number of air pollution facilities, X28: number of water pollution facilities), and economic dimensions (X31: number of people living in poverty per 1,000 inhabitants, X32: women’s job opportunity, X35: economic self-sufficiency), also played an important role in guiding the pattern of sustainability in the region during the period of 1990-2000.

From this study, it is concluded that although there were some variations in elements affecting the pattern of sustainability for each year, key elements influencing the pattern of sustainability remained relatively stable over the study period. Consequently, Hypothesis 5 was not supported.

Table V-30. Key elements by factor, 1990-2000.

Factor	1990	1995	2000
Factor 1	X1, X2, X3, X7, X10, X11, X12, X15, X18, X19, X20, X21, X22, X31, X32, X33, X35, X37	X1, X3, X7, X8, X10, X11, X12, X15, X16, X18, X19, X20, X21, X22, X31, X32, X35, X37	X2, X7, X10, X12, X14, X15, X16, X18, X20, X21, X22, X31, X32, X35, X37
Factor 2	X9, X26, X27, X28, X30	X2, X9, X14, X27, X28, X36	X14, X27, X28, X34
Factor 3	X9, X11, X20, X34, X38	X26, X30, X33, X34	X1, X11, X26
Factor 4	X13, X16, X23	X13, X38	X13, X19, X23, X38
Factor 5	X5, X6	X4, X17, X23	X5, X26, X30, X33
Factor 6	X17, X24	X5, X6, X29	X17, X23, X29
Factor 7	X8, X25	X18, X37	X8, X36
Factor 8	X4, X29	X25	X3, X25
Factor 9	-	X24	X24

CHAPTER VI

SUMMARY AND CONCLUSIONS

6.1 Introduction

This chapter summarizes the major findings of this research, and discusses policy implications and recommendations for overcoming the negative impacts of urban growth and change on achieving sustainability. This chapter also addresses limitations of the research and directions for future research.

6.2 Summary

The main purpose of this research was to obtain a better understanding of the impact of urban growth and change on sustainability based on a comparative study of 31 municipalities comprising Gyeonggi Province in the Seoul Metropolitan Region over the 1990-2000 period. The specific objectives of the research were set: to identify the patterns of growth and change in the study areas; to measure and assess progress toward sustainability in the study areas based upon a set of sustainability indicators; to examine the impact of urban growth and change on sustainability and to identify the key elements affecting the pattern of sustainability in the study areas; and to explore the policy and planning implications for achieving sustainable development.

A process of population decentralization within the Seoul Metropolitan Region emerged from the mid-1980s. In particular, the suburban areas within the commuting distance from Seoul began to grow rapidly throughout the 1980s and 1990s, accommodating population and economic activities from Seoul. The large-scale urban development projects such as the construction of five new towns in the 1990s, accelerated the growth of suburban areas. As a result, the Province of Gyeonggi has grown fast through rapid increase of population during the 1990s.

In order to examine the impact of urban growth and change on achieving sustainability, this study selected 38 sustainability indicators based upon careful review of the relevant literature and the data quality and comparability, and then measured progress towards sustainability in 31 study areas for the years 1990, 1995 and 2000.

This research led to five major findings. The first finding stems from testing Hypothesis 1, which argues that the level of urban sustainability tends to be higher in more densely populated areas than in less densely populated areas within a region. This hypothesis focuses on examining whether there is a difference in the level of sustainability among the study areas with different population densities for the years 1990, 1995 and 2000. This study found that the study areas with higher densities showed the lower mean values of sustainability. This result indicates that the level of sustainability is not higher in more densely populated areas than in less densely populated areas in the Seoul Metropolitan Region.

The second finding comes from testing Hypothesis 2, which assumes that the trend of sustainability in urban areas with green belt tends to be stable over time, however, the trend of sustainability in their surrounding areas tends to decrease over time. This hypothesis aims to examine the relationship between cities' growth limitation measure and its impact on sustainability of the cities and their surrounding areas. This study found that the two subject areas showed different trends towards sustainability over time. The level of sustainability has increased in urban areas with green belt over time, but the mean differences were not statistically significant during the 1990-2000 period. On the contrary, the level of sustainability has declined in their surrounding areas over time. In particular, there was a significant decline between 1995 and 2000.

The third finding emerges from testing Hypothesis 3, which contends that the degree of sustainability of a region becomes greater over time. This hypothesis aims to examine the pattern of change in the level of sustainability of a region over time. For the entire region, the overall level of sustainability has not improved over the 1990-2000 period. However, different trends of sustainability have emerged within different parts of the region over the same period. The level of sustainability in the over-concentration control zone has increased over time. In particular, there was a significant improvement between 1995 and 2000. For the growth management zone, the level of sustainability continued to decline over time. It has declined significantly between 1995 and 2000. The level of sustainability in the nature preservation zone has decreased over time. But there were no statistically significant differences among mean levels of sustainability during the 1990-2000 period.

The fourth finding comes from testing Hypothesis 4, which assumes that different patterns of sustainability tend to emerge within different parts of a region. That is, the locational patterns of sustainability within a region tend to differ according to the patterns of growth and change in its sub-regions. This hypothesis aims to examine the difference in the pattern of sustainability in different parts of the region. This study found that there were significant differences in the mean values for the level of sustainability among three zones within the region during the 1990-2000 period. Specifically, there were significant differences in the means between the growth management zone and the nature preservation zone, and between the nature preservation zone and the over-concentration control zone in 1990 and 1995. In 2000, there was a significant difference in the means between the growth management zone and the nature preservation zone. Overall, the level of sustainability was much higher in the nature preservation zone than in the growth management zone and the over-concentration control zone during the 1990-2000 period.

The fifth finding stems from testing Hypothesis 5, which argues that key factors affecting the pattern of sustainability within a region tend to change over time. This hypothesis attempts to identify the key drivers influencing the pattern of sustainability in the region during the 1990-2000 period. This study found that although there were some variations in elements affecting the pattern of sustainability for each year, key elements influencing the pattern of sustainability remained relatively stable over the study period.

6.3 Policy Implications and Recommendations

This study has explored the trend towards sustainability in 31 study areas comprising Gyeonggi Province in the Seoul Metropolitan Region, and the factors influencing such a trend, using analytical methods with the data for 1990, 1995, and 2000. Based upon research findings, this study makes the following policy recommendations for overcoming the negative impacts of urban growth and change on achieving sustainability.

First, this study found that increased density does not necessarily result in improved urban sustainability. This implies that the usefulness of the compact city model varies across time and place. As mentioned earlier, sustainability covers a variety of spheres of cities. Sustainability relates to the way in which cities use economic, social and natural resources. Compact urban development can serve as one of important elements in achieving sustainability. However, higher densities alone may not be the effective solution. In general, in most of the cities in developing countries, residential densities are much higher compared to cities in developed countries. Compact development may cause negative impacts such as pollution and urban infrastructure overburden under conditions where densities are already high. Therefore, promoting compact development as a strategy for achieving sustainability in cities in developing countries needs to be approached cautiously.

Second, this study revealed the possibility that cities' growth control policy could produce unintended consequences within their neighboring metropolitan areas. As mentioned earlier, a greenbelt, one of powerful growth management tools, contributed to restricting an expansion of existing urban areas, but moved increasing development pressure to their adjacent urban areas outside the greenbelt in the Seoul Metropolitan Region. As a result of this process, a greenbelt contributed to stability in the pattern of urban growth and change in urban areas with green belt over the 1990-2000 period, which resulted in a relatively stable trend towards urban sustainability. However, their surrounding areas without such a powerful urban containment system have experienced a rapid, uncontrolled growth during the 1990s and thus their overall sustainability has deteriorated significantly. These results imply the possibility that whereas a growth control measure such as green belt may not be able to make a significant contribution to achieving sustainability in urban areas, it could have a negative effect on sustainability in their surrounding areas by creating side effects such as a leapfrog urban development in areas beyond the green belt’s outer boundary. In this respect, urban sustainability issues need to be approached from a regional perspective.

In particular, the supply of affordable housing is one of the most important challenges most mega-cities in developing countries face. As in most mega-cities in developing countries, Seoul has experienced a chronic shortage of housing. Evidence of a housing crisis in Seoul includes high apartment rents, high housing prices, and an insufficient supply of housing units. In order to solve the housing shortage problem in Seoul, massive housing developments, including the construction of 5 new towns along the periphery of Seoul in the 1990s, took place in surrounding Gyeonggi Province and thus the housing sector has had an enormous effect on the spatial structure of the Seoul Metropolitan Region. One of the main factors associated with the rapid population growth in Gyeonggi Province was continued housing development.

In this respect, ongoing housing developments in Gyeonggi Province to mitigate the housing shortage of Seoul may pose a potential threat to municipalities’ efforts in achieving sustainable development. Uneven, poorly planned developments have been criticized for increasing the threat to the long-term sustainability of metropolitan regions (Sierra Club, 2001). Therefore, to achieve regional sustainability, central and local governments need to develop strategies to help more efficiently distribute the location, type and intensity of growth across the Seoul Metropolitan Region.

Third, this study revealed that the sustainability in rapidly growing areas has deteriorated significantly over time. In general, local governments try to take full advantage of the benefits and opportunities of growth. However, at the same time, they need to minimize the negative impacts of growth. In this respect, in order to achieve sustainable development in fast growing municipalities, it is important to control the speed and magnitude of growth. For fast growing municipalities in the Seoul Metropolitan Region to improve urban sustainability, there is a need to take more active measures to control rapid growth and change through various growth management policies such as tying development to infrastructure capacity, setting limits on the number of new housing units, or the adoption of urban growth boundaries.

Fourth, despite the difference in the pattern of overall sustainability in the study areas over the 1990-2000 period, key elements influencing the pattern of sustainability remained relatively stable over time. They included sustainability indicators associated with population, transportation, health, housing, education, environment, and economy. This result implies that these elements can play a critical role in achieving sustainability in the Seoul Metropolitan and thus pose a serious challenge to policy makers who seek strategies towards sustainability. In this respect, local governments need to put more focus on these elements in seeking sustainability.

Fifth, to create sustainable urban management policies in a metropolitan area, there is a need for better integration of local and central governments' policies. As stated earlier, the central government relaxed the regulation of agricultural land use in the early 1990s to promote the supply of housing in the Seoul Metropolitan Region. On the other hand, local governments were not given proper tools to manage and direct growth in a sustainable way.

As a result, massive residential development and the resulting rapid growth have occurred in Gyeonggi Province during the 1990s.

Local governments have a responsibility to develop urban policies that manage and guide growth. They also must take the lead in mitigating the negative impacts of growth. In this respect, local government's responsibilities to address site-specific planning decisions in their communities must be respected. However, in reality, due to a tradition of the highly centralized planning system in Korea, the autonomy of local governments in urban planning and policies has been limited. As a result, in the process of deciding the location and amount of growth within the Seoul Metropolitan Region, local governments have not played a substantial role. Therefore, there is a need to provide local governments with more autonomy in planning and land use decision-making. The central government needs to focus on planning issues that no single local government can individually address and manage. In other words, it is suggested that the central government focus on establishing a set of guiding principles for planning and growth management in the Seoul Metropolitan Region and implementing a regional system to monitor and measure progress in achieving regional planning and growth management goals, while local governments develop specific implementation tools. In addition, taking into account the Seoul Metropolitan Region's fragmented and competitive land use planning structures, it is also important to establish and maintain an effective mechanism for improving collaboration between levels of government.

Sixth, for local governments to enhance sustainability, they need to monitor progress towards sustainability on a regular basis and adapt urban policies to changing circumstances. In order to do so, local governments need to adopt a sustainability indicators program and turn it into an ongoing process. In particular, cities experiencing rapid urban growth and change in developing countries need to increase their capacity to promote urban sustainability by adopting a sustainability indicators program in that they face serious sustainability challenges.

Sustainable development is of critical importance for all citizens. It requires efforts from society as a whole. Achieving sustainability implies that compatible sustainable development goals be brought into the decision-making processes of individuals, private and non-profit organizations (Barton, 2000; OECD, 2002a). In this respect, for the sustainability indicators program to operate efficiently, it should be based upon the participatory process to promote the participation of various stakeholders in setting sustainability goals, developing sustainability indicators, monitoring progress towards sustainable development, and providing better policy solutions. The government commitments would become useless if they were not to be paralleled by similar commitments by the private sector and civil society (OECD, 2002a).

As Healey (1997) stated, planning is part of processes which have the potential to shape the building of relations and discourses, the social and intellectual capital, through which links are made between networks to address matters of shared concern at the level of neighborhoods, towns and urban regions. Working in between many affected parties or stakeholders (individuals, households, firms, public institutions, associations, pressure groups, and various informal groups), planners and policy makers face a central challenge of democratic politics: the challenge of making public deliberation work, making participatory planning a pragmatic reality rather than an empty ideal (Forester, 1999; Hoch, 1994). In the process of seeking urban sustainability, planners and policy makers have to be bridge builders, negotiators, and mediators in the midst of various actors.

In addition, local governments also need to develop an urban information management system that enables them to monitor and track progress towards sustainability, and measure and predict the impacts of growth by continuing to collect, analyze and report data. A wide variety of data and information needs to be collected and analyzed to track and evaluate progress towards sustainable development. It is impossible to develop a set of sustainability indicators and measure progress towards sustainable development without data. A well-developed urban information management system will help local governments identify and overcome challenges for urban sustainability and facilitate studies of urban sustainability as well.

6.4 Limitations and Directions for Future Research

This study provides a better understanding of the prospects and problems of moving towards sustainability in a rapidly growing metropolitan region in developing countries by dealing with the sustainability impacts associated with urban growth and change. However, this study has some limitations. Further research is needed in order to better understand the interrelationship between urban growth and sustainability.

First, this study has made an attempt to examine the impact of urban growth and change on sustainability based upon municipalities' experience in the Seoul Metropolitan Region, Korea. They have different characteristics from other municipalities in history, physical characteristics, governmental policies, and economic bases. Thus, research findings may have limitations in generalizing to municipalities in other metropolitan regions. Thus, examining other cases under various circumstances is needed to add more empirical evidence.

Second, 38 sustainability indicators were used in this study because of the limited data availability. Urban sustainability encompasses a variety of aspects of cities. Thus, research based upon more sustainability indicators would help provide more accurate, detailed information on progress towards sustainability.

Third, each of the 38 sustainability indicators was not given weight in this study. Further research is needed based upon differential weighting among sustainability indicators. The level of development varies over a city or country and thus each city and country's target for achieving sustainability is different. For instance, of three aspects of the concept of sustainable development, developed countries tend to emphasize environmental protection, while developing countries tend to focus on economic growth. Giving weight may help reflect the characteristics of the subject area.

Fourth, the pattern of urban growth and change and progress toward sustainability evolve through the long time period. Thus the time span of this study (1990-2000) may not provide thorough information about the causal relationship between the pattern of urban growth and change and sustainability. Therefore, the study with the longer time span needs to be conducted.

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APPENDIXES

APPENDIX A

Z-SCORES, 1990

Table A-1. Z-scores, 1990.

Area	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10
Ansan	-3.69377	-0.40044	-1.20371	1.95251	-0.55847	-1.49771	-0.32378	5.01976	-1.08842	-1.3815
Anseong	0.86904	0.63171	1.21935	0.12938	0.67327	0.04283	-0.94061	-0.15673	0.49843	0.54549
Anyang	-0.12648	-1.98461	-0.7191	0.55011	-1.29033	0.22829	0.58864	-0.187	-0.50703	-1.07342
Bucheon	-0.49852	-3.48185	-1.20371	0.91473	0.58674	-1.97729	0.18645	-0.14159	-0.09664	-0.74473
Dongducheon	0.67455	0.45653	-0.7191	-2.80632	-1.17157	1.14436	-0.94061	-0.42918	0.5292	1.13909
Gapyeong	1.09521	0.68204	-1.20371	1.00823	-1.73313	1.97801	-0.94061	-0.42918	0.65403	2.40479
Gimpo	0.70039	0.58432	0.73473	0.57815	1.42539	-1.17798	-0.77063	-0.42918	-0.67461	0.48368
Goyang	-0.14593	0.40129	-0.23449	-0.67466	0.80399	-0.54728	0.51373	-0.3535	0.46423	-1.18135
Gunpo	-1.70132	-0.87664	-1.20371	1.22326	0.05004	-0.33497	0.36766	-0.14159	-0.51045	-0.35521
Guri	-0.05119	-0.48672	-0.23449	-1.60025	0.35015	-0.55041	1.29622	-0.14159	-0.13255	0.03823
Gwacheon	0.48172	0.04177	-1.20371	-0.12305	-1.10253	0.81278	1.71598	0.84224	-3.08565	-1.40309
Gwangju	0.52646	0.6438	0.25012	-0.28199	-0.94143	1.17559	-0.22986	-0.42918	-1.86645	1.35495
Gwangmyeong	-0.59271	-2.0637	-1.20371	-0.04825	0.57845	-0.75773	1.26885	-0.14159	1.37392	-1.66604
Hanam	0.12802	0.32481	0.25012	-0.02956	-0.22245	0.32633	1.89634	-0.42918	1.63726	-0.05007
Hwaseong	0.64399	0.61798	2.18857	-0.35678	1.17039	-0.48671	-0.42001	-0.42918	0.21286	0.04706
Icheon	0.26111	0.59674	1.21935	0.36312	1.48707	-0.5604	-0.94061	-0.06591	-0.29842	0.571
Namyangju	-0.12065	0.56111	-0.23449	0.30702	-0.90461	1.34294	0.55752	-0.41404	0.7515	-0.52495
Osan	0.10969	0.22251	0.25012	-0.02956	1.54322	-1.04747	-0.94061	-0.21727	-0.74813	1.24506
Paju	0.44977	0.61243	1.70396	-1.6657	0.49652	-0.01525	-0.94061	-0.42918	0.70704	0.01665
Pocheon	0.72929	0.65688	-0.23449	-0.22589	-0.74995	1.12938	-0.94061	-0.42918	-0.12058	1.26861
Pyeongtaek	0.50812	0.49902	0.25012	-0.76816	2.48682	-1.65132	-0.94061	-0.11132	-0.01969	0.11084
Seongnam	0.21249	-0.54621	-0.7191	-1.46001	-0.61462	0.23578	0.1732	0.55466	0.71388	-0.87326
Siheung	-1.74745	0.43561	-0.7191	0.35377	0.80584	-0.65719	1.68141	-0.42918	0.03332	-0.5799
Suwon	-0.59188	-1.29531	-0.23449	0.90538	0.16603	-1.36345	-0.15524	0.87251	-0.77891	-1.05674
Uijeongbu	-0.05924	-0.14681	-0.7191	-1.19823	-0.85029	0.65667	1.3089	-0.21727	0.10855	-0.53378
Uiwang	-1.32706	0.10877	-0.23449	0.73709	-0.54466	0.76407	1.74479	0.46384	-0.10177	-0.97923
Yangju	0.40365	0.61047	0.25012	0.32572	-0.14697	0.6448	-0.19039	-0.42918	-0.56004	0.13733
Yangpyeong	1.06604	0.67289	-0.23449	1.09237	-1.09517	1.43973	-0.88068	-0.42918	1.85955	1.35201
Yeoju	0.68316	0.64969	1.21935	0.57815	0.16879	0.19394	-0.94061	-0.42918	0.60444	0.99977
Yeoncheon	0.94045	0.6742	0.73473	-0.46898	-0.64132	-0.11516	-0.94061	-0.12646	1.20122	-0.07264
Yongin	0.17304	0.59772	2.18857	0.71839	-0.22522	0.62482	-0.92303	-0.187	-0.7601	0.76135

Table A-1 (continued).

Area	x11	x12	x13	x14	x15	x16	x17	x18	x19	x20
Ansan	-0.98827	0.45945	-0.53437	-0.38962	1.35003	1.83317	0.56923	-0.43775	-2.62419	0.47235
Anseong	0.59336	0.77301	-0.7447	0.14229	-1.13476	0.46841	-0.57934	1.31581	1.70106	-0.45307
Anyang	-0.76331	-0.74038	-1.80633	0.16824	1.24354	1.5431	1.0391	-0.50172	-0.23415	0.93316
Bucheon	-0.51309	-1.00661	-0.00995	0.38878	1.20804	0.63956	2.15635	-1.18056	0.10355	0.68943
Dongducheon	0.67141	0.54346	0.17623	-2.58862	0.78208	-1.00166	-0.03638	-0.15025	-0.25782	-0.61302
Gapyeong	0.64387	1.91722	0.98773	0.42122	-0.35382	-0.65937	-0.26609	1.17432	0.89981	-0.50067
Gimpo	0.29494	-0.05764	0.28566	0.53798	-1.20575	-1.08021	-0.78817	0.66481	0.99202	-0.6035
Goyang	-0.5108	-1.36159	-0.00853	-1.17451	-0.24733	-0.40924	-0.51669	0.05671	-0.66281	0.32193
Gunpo	-0.05628	-0.54514	0.71344	-1.74535	0.81757	0.82869	-0.84038	-1.32883	-0.27278	0.45903
Guri	0.12737	-0.54632	-0.9593	-0.65558	1.03055	0.3236	0.62144	-1.5674	-0.40487	-0.27979
Gwacheon	-4.09415	-1.79821	1.81344	0.33689	1.06605	0.97306	-0.64199	0.74233	-0.9868	4.35684
Gwangju	0.21919	1.11379	-1.81344	-1.85562	-1.45423	-0.58916	-0.33918	-0.28572	0.13719	-0.76535
Gwangmyeong	-1.22471	-1.85619	-0.05969	0.74555	1.13705	0.18932	-0.37051	-0.02908	-1.49147	1.01123
Hanam	0.09523	-0.21619	-1.81344	-0.22745	0.17863	-0.09329	-0.29742	-2.18152	-1.22605	-0.40165
Hwaseong	1.00886	0.15062	0.523	0.60285	-1.59622	-0.73836	-1.41466	1.10509	1.25495	-0.72155
Icheon	0.17098	1.39185	-0.45478	0.81691	-1.09926	0.7361	0.88248	0.52408	0.73657	-0.27027
Namyangju	-0.37536	-0.84095	-0.96072	1.14124	-0.35382	-0.88537	-0.81949	0.18992	-0.26904	-0.26075
Osan	0.99049	0.98008	0.52158	0.86232	0.78208	-0.14156	1.94752	-0.34442	-1.24973	-0.45116
Paju	0.50154	-0.1026	1.64574	0.97259	-0.56681	-1.51509	-1.01788	0.85974	1.04311	-0.64539
Pocheon	0.70585	1.10432	0.00853	0.90124	-1.13476	1.08716	-0.42271	1.02757	0.82131	-0.62444
Pyeongtaek	0.01259	0.79431	-0.81434	-0.7918	-0.10535	-0.6484	1.1644	0.47516	-0.13446	-0.1922
Seongnam	0.38217	-0.38422	-0.8783	0.15526	1.13705	1.56987	0.611	-1.85188	-0.30642	-0.14459
Siheung	-0.20778	-1.32609	1.67274	-0.3507	0.10764	-0.8744	-0.93435	-0.12241	-0.09832	-0.0551
Suwon	-0.58196	-0.00202	0.04548	0.30446	1.13705	0.46885	1.15396	-0.74631	-0.24786	0.65706
Uijeongbu	-0.23304	-0.52029	0.17765	-0.55179	0.85307	0.31921	1.57162	-1.33485	-0.43477	0.01345
Uiwang	-1.06173	-1.24563	0.71344	0.4796	0.60459	0.65711	1.08087	-0.16606	-0.98555	1.32732
Yangju	1.041	0.15298	0.17765	-1.72589	-1.09926	-1.51947	-1.3729	0.30959	0.06492	-0.66062
Yangpyeong	0.86883	0.87004	0.36667	1.53045	-1.34774	-1.87931	-0.55845	1.50622	1.55277	-0.69299
Yeoju	0.63009	1.61667	1.05168	1.08286	-1.34774	-0.13541	-0.63155	1.21572	1.74343	-0.76154
Yeoncheon	0.97442	-0.10378	1.22933	0.79096	0.35611	-0.949	-1.40422	1.26614	0.76025	-0.653
Yongin	0.6783	0.78603	-1.25207	-0.32475	-0.74429	1.4821	0.45438	-0.20444	0.07613	-0.49115

Table A-1 (continued).

Area	x21	x22	x23	x24	x25	x26	x27	x28	x29	x30
Ansan	-1.52922	-1.17613	0.17307	0.99634	-1.89415	-1.49046	-2.12375	-2.24199	1.5485	0.99445
Anseong	0.94228	1.32634	-1.82495	-0.9372	-0.59224	0.68105	0.11331	-0.07204	-0.75684	-0.1578
Anyang	-1.0499	-1.26061	-1.18979	1.09646	-0.8048	0.31208	0.83377	0.76312	1.42284	-0.73484
Bucheon	-1.17187	-1.09589	-0.42378	0.3487	-1.62846	0.62501	0.64454	0.66932	-0.0462	-0.70345
Dongducheon	0.26396	-0.1498	-0.63762	-1.1828	-0.1937	0.72545	-0.77395	-1.1507	-1.07211	-0.74521
Gapyeong	1.83673	1.89864	1.23911	0.78672	0.12513	1.401	0.76368	0.42761	1.08773	-0.40898
Gimpo	0.7283	0.41405	1.4753	0.18757	1.45361	-0.21335	-0.87066	0.09391	0.10592	0.86398
Goyang	-0.2603	-0.0421	0.91355	-0.15346	1.34733	0.59013	1.00477	0.88758	-1.18528	-0.11818
Gunpo	-2.03208	-1.68085	-1.25682	-0.67595	-0.75166	-1.15004	0.43429	0.38252	2.02471	0.14885
Guri	-0.63691	-0.57638	-0.92169	-1.07017	-0.51254	0.80157	0.98655	0.59356	-3.42301	-0.81837
Gwacheon	-0.62193	-0.9734	-0.16525	1.32798	-0.61881	-0.47025	1.24445	1.39625	-0.35706	-0.448
Gwangju	0.61703	0.79628	-0.68869	-1.28292	1.85216	0.15244	-1.24631	-0.47248	0.2235	0.48935
Gwangmyeong	-1.19112	-0.95228	-1.24405	-1.19688	0.1517	1.05318	1.10709	1.22849	-0.26226	-1.14789
Hanam	-0.85517	-0.59117	-0.50676	0.46759	-0.64538	-0.50408	0.30814	0.64226	0.8555	-1.15124
Hwaseong	0.89521	1.02436	-1.25044	-1.46282	0.89565	-1.26739	-1.25892	-0.63482	-0.77889	2.21468
Icheon	0.6855	0.43305	0.15712	0.76951	0.31112	-0.19644	-0.13338	0.22379	-0.29239	1.55625
Namyangju	-0.15117	-0.04632	0.22095	-1.42214	-0.35312	0.80685	0.63613	0.86413	-0.70907	-0.62084
Osan	-0.32877	-0.6503	0.36777	1.40307	1.40047	-1.62472	-0.75152	-0.44542	-0.1873	0.93166
Paju	0.83957	0.80473	0.40607	-1.12648	1.85216	0.53938	-0.12778	0.06325	0.65929	-0.45349
Pocheon	1.04927	1.13206	1.65723	-0.7792	0.81594	0.04778	-0.27635	-1.38339	0.70338	-0.36753
Pyeongtaek	0.39663	-0.11179	0.61034	1.73002	-1.15021	-0.29581	0.00678	0.09932	-0.85605	0.73809
Seongnam	-0.78242	-0.96495	0.33585	1.37804	-1.78788	0.78782	1.06504	1.15634	0.68722	-1.22257
Siheung	0.09277	-0.21527	0.94866	0.72101	-0.03428	-2.06981	-1.80277	-1.45915	0.27347	0.68078
Suwon	-0.7974	-1.15924	0.44756	0.50513	-0.67195	0.54467	1.00337	0.801	-0.13659	0.03546
Uijeongbu	-0.36943	-0.80446	-0.46208	0.78984	0.07199	0.80157	1.08046	0.74869	-0.02563	-1.1677
Uiwang	-1.21894	-0.77278	-0.90573	0.92594	-0.1937	-0.01248	0.50578	0.33382	0.26612	-0.27211
Yangju	0.01574	1.15318	1.75298	-0.15815	0.1517	-1.12678	-2.21206	-2.74164	0.35211	0.51191
Yangpyeong	1.72546	1.77405	1.57424	-1.01072	0.39083	1.23819	0.66697	0.78116	0.04492	-0.81806
Yeoju	1.36383	1.27988	0.21457	0.35339	1.18792	0.48546	-0.01564	-0.54463	-0.65763	-0.13829
Yeoncheon	1.2868	0.96945	0.47629	-0.30051	-0.06085	1.0701	0.17919	-0.47067	-0.10867	-0.59157
Yongin	0.25754	0.21765	-1.49301	-1.02793	-0.11399	-2.24213	-0.9912	-0.53922	0.59976	2.92066

Table A-1 (continued).

Area	x31	x32	x33	x34	x35	x36	x37	x38
Ansan	1.01482	-1.71307	1.11249	-0.94165	0.98275	-1.02853	-2.28687	-0.35072
Anseong	-1.6289	1.90217	-1.56251	-0.46948	1.11278	-0.08061	1.53441	-0.09918
Anyang	0.78562	-0.1146	1.13699	0.38074	-0.98615	-1.15779	-0.85682	-0.35072
Bucheon	0.93842	-0.90039	1.19671	-0.43212	-0.87488	-1.37323	-1.32569	-0.06191
Dongducheon	0.17665	0.59351	0.5582	-0.00477	0.51452	1.72904	1.18276	-0.09918
Gapyeong	-3.13052	-0.50002	-1.1399	0.88728	1.4453	0.65187	1.27653	0.2828
Gimpo	-0.48006	-0.90338	-0.34215	-0.91924	0.72442	-0.38222	0.22158	0.16169
Goyang	0.13677	-0.59264	0.39742	-0.51729	-0.85044	0.56569	-1.27880	-0.35072
Gunpo	0.75135	-0.69423	1.19058	-1.05521	-0.9159	-0.59766	-0.59894	-0.35072
Guri	0.42608	-0.11161	0.89047	1.09647	-0.79808	0.09173	-0.17696	-0.05259
Gwacheon	1.17998	-1.12148	0.76338	3.32736	-1.81002	0.47952	-0.57550	5.24847
Gwangju	-0.25704	0.22004	-0.15381	-0.70855	1.05475	-0.20988	-0.13007	-0.18302
Gwangmyeong	0.95808	-0.09966	1.26408	0.10879	-1.71882	-1.50249	-0.50517	-0.35072
Hanam	0.52046	-1.34856	0.40814	0.17902	-0.93946	-0.59766	-0.76305	-0.35072
Hwaseong	0.04969	1.87827	-1.36499	-0.78775	0.18637	-1.20088	0.17469	-0.35072
Icheon	-0.06267	1.23888	-0.7862	-0.20649	1.46275	0.13482	0.97177	-0.22029
Namyangju	0.0025	-1.24697	0.41886	-0.94912	-0.66935	-0.59766	-0.71616	-0.15507
Osan	0.79966	0.65626	0.31933	-0.16615	0.14754	1.72904	-0.24729	-0.35072
Paju	-0.06042	-0.06082	-0.75557	-0.18707	0.50143	-0.03753	1.13587	-0.32277
Pocheon	-1.25475	0.62937	-1.25781	-0.01374	1.29388	1.59978	1.46408	-0.13644
Pyeongtaek	-0.12671	0.41424	-0.49986	0.34936	0.15103	-0.94236	0.29191	0.03126
Seongnam	0.69236	0.29473	0.89659	0.32994	-0.68942	-1.02853	-0.45828	0.57161
Siheung	0.37833	-0.34167	0.64854	-1.01039	-1.19779	-0.29605	-0.78649	-0.35072
Suwon	0.94685	-0.18929	0.98081	1.39383	-0.55415	-0.81309	-1.18503	0.16169
Uijeongbu	0.63675	-0.61953	0.83687	2.11404	-0.35429	0.95347	-0.34106	-0.07123
Uiwang	0.61652	-0.47313	0.92722	-0.84901	-1.37583	0.35026	-0.78649	-0.35072
Yangju	0.17721	-1.42624	-0.98219	-1.04326	0.48398	1.16891	0.76078	-0.35072
Yangpyeong	-1.45475	1.24485	-1.75698	-0.16167	0.84354	-0.20988	0.64356	-0.35072
Yeoju	-0.99297	0.91619	-1.15522	-0.07649	1.24457	1.68596	1.20620	-0.32277
Yeoncheon	-1.90754	0.43217	-1.56251	1.04418	0.49576	1.64287	1.72196	-0.35072
Yongin	0.16822	2.03662	-0.62695	-0.71154	1.08922	-0.72692	0.43257	-0.17371

APPENDIX B

Z-SCORES, 1995

Table B-1. Z-scores, 1995.

Area	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10
Ansan	-2.05659	-0.26799	-2.24197	2.33509	-0.36815	-0.67057	-0.15842	3.18357	0.04201	-1.36380
Anseong	0.49072	0.65499	1.5663	-0.07825	0.76476	0.03332	-0.95839	-0.06154	0.1086	1.59390
Anyang	0.01023	-2.1367	-0.33783	0.10931	-1.78699	0.16667	0.5786	0.68396	0.57833	-0.89447
Bucheon	0.18722	-3.38926	-0.33783	0.12182	0.23517	-2.0337	0.14932	0.0481	0.8792	-0.48651
Dongducheon	0.58613	0.50411	-0.33783	-2.8042	-1.03891	1.17691	-0.95839	-0.76318	0.87563	0.00809
Gapyeong	0.42588	0.69994	0.61424	0.6345	-1.54602	2.02422	-0.95839	-0.76318	1.13487	2.02623
Gimpo	0.77137	0.60779	-0.33783	-0.29083	1.50924	-1.24992	-0.76115	-0.59873	-1.24708	0.60379
Goyang	-2.82836	0.12508	-1.2899	1.10966	0.73149	-0.8033	0.50057	1.73643	0.17995	-1.03347
Gunpo	-3.22222	-1.17495	-0.33783	1.04714	-0.60103	-0.33027	1.01106	2.2517	0.51055	-0.97209
Guri	-0.19441	-0.49473	-1.2899	-0.7785	-0.01839	-0.65548	1.0772	-0.44525	1.0552	-0.61107
Gwacheon	0.71077	0.16667	-2.24197	0.19684	-0.93281	0.82402	1.71328	0.19062	0.13714	-1.09755
Gwangju	0.06444	0.65752	-0.33783	0.30938	-0.81143	1.17314	-0.24283	-0.76318	-1.49681	0.16695
Gwangmyeong	0.51305	-1.79392	-0.33783	-0.69097	0.19291	-0.66806	1.2869	-0.1602	1.59033	-0.82046
Hanam	0.2146	0.36447	-0.33783	-0.45338	-0.36815	0.18429	1.72778	-0.33562	0.98979	-0.35474
Hwaseong	0.96617	0.65106	0.61424	-0.60344	1.29165	-0.59509	-0.55289	-0.76318	-0.4301	0.90795
Icheon	0.50321	0.62296	0.61424	1.12217	1.57218	-0.57433	-0.95839	-0.53295	-0.82135	1.05146
Namyangju	0.14072	0.57295	-0.33783	-0.51591	-0.76467	1.18383	0.56613	-0.76318	0.39401	-0.43146
Osan	0.17845	0.25939	0.61424	-0.22831	1.50745	-1.06561	-0.95839	-0.57681	-0.40037	-0.04155
Paju	0.87262	0.64881	0.61424	-1.19114	0.60291	-0.06544	-0.95839	-0.70836	0.04438	-0.15888
Pocheon	0.21327	0.67438	0.61424	0.04679	-0.65768	1.17817	-0.95839	-0.64258	-0.74286	1.41790
Pyeongtaek	0.14284	0.51113	0.61424	-0.60344	2.46772	-1.7305	-0.95839	0.5524	-0.0127	-0.22296
Seongnam	-1.07142	-1.04093	0.61424	-0.75349	-0.85099	0.09371	0.16121	1.58294	0.75195	-1.02895
Siheung	-0.17182	0.40071	-0.33783	1.15968	0.8232	-0.90143	1.65498	1.00189	-0.88675	-0.38001
Suwon	0.21327	-1.01621	-0.33783	0.43443	0.53098	-1.43108	-0.08504	0.14677	-0.10783	-0.89086
Uijeongbu	-0.23082	-0.24776	-0.33783	-1.61629	-0.78355	0.6221	1.3017	-0.46717	0.79476	-1.00007
Uiwang	0.2813	0.14616	-0.33783	1.15968	-0.57495	0.69507	1.71647	0.01521	0.15022	-0.64356
Yangju	0.31559	0.63195	0.61424	-0.14077	-0.04446	0.6611	-0.21876	-0.76318	-0.882	0.66877
Yangpyeong	0.58214	0.69292	0.61424	0.83457	-0.92382	1.4908	-0.90154	-0.76318	1.27044	2.50459
Yeoju	0.63583	0.67353	2.51837	-0.31584	0.37993	0.19372	-0.95839	-0.76318	-0.33616	1.11735
Yeoncheon	0.91939	0.69404	1.5663	-0.70347	-0.39153	0.54347	-0.95839	-0.52199	-3.35433	0.29421
Yongin	-0.16358	0.60189	-0.33783	1.14717	-0.14607	0.53026	-0.94069	-0.23695	-0.76902	0.07127

Table B-1 (continued).

Area	x11	x12	x13	x14	x15	x16	x17	x18	x19	x20
Ansan	-1.66336	-0.27325	0.31522	0.4152	1.06945	1.8225	-0.21941	-1.6868	-1.15224	0.24752
Anseong	1.80509	1.27592	0.43628	-0.66086	-1.11625	-0.00982	-0.19742	1.23701	1.69523	-0.58281
Anyang	-0.30959	-0.91863	1.23463	1.03206	1.0269	1.60282	0.62347	-0.09595	-1.20527	1.02371
Bucheon	0.03593	-0.83165	0.6623	1.01823	1.06171	1.01868	0.64546	-0.79479	-0.42794	0.4067
Dongducheon	0.21719	0.30785	-1.45158	-0.8296	0.71742	-0.79867	0.17638	0.11138	-0.19424	-0.7584
Gapyeong	1.1688	1.05281	-0.00504	-0.13251	-0.98085	-1.04332	-0.43929	1.3068	0.70409	-0.81255
Gimpo	0.23607	0.46163	0.08077	-0.13251	-1.18588	-0.17958	-0.35867	0.58773	1.10684	-0.42856
Goyang	-2.10706	-1.78712	0.97643	0.47329	0.71355	1.38814	-0.93035	0.09216	-0.70639	1.33714
Gunpo	-0.83259	-1.24006	1.05611	0.86609	1.09266	0.3846	-0.88638	0.08104	-1.29312	1.15007
Guri	-0.33602	-0.61863	-0.13529	0.87992	1.0385	0.53937	2.54376	-1.65039	-0.69313	-0.06098
Gwacheon	-1.52742	-1.21485	-3.94319	0.55904	0.99595	1.24335	-0.49059	-0.06662	-2.69862	3.69031
Gwangju	0.50418	0.43516	-0.34906	-3.36068	-0.9499	-1.66741	-0.10947	-1.32272	0.26818	-0.8946
Gwangmyeong	-0.01127	-1.40141	0.31522	1.58531	1.08879	0.40457	-0.74712	0.07396	-0.31523	0.83664
Hanam	0.05104	-0.58838	-0.34906	-0.74384	0.14875	0.38959	-0.71047	-2.29665	0.33614	-0.15124
Hwaseong	1.50299	0.9734	0.31292	-0.34551	-1.60368	-0.85359	-1.17222	1.05497	1.10353	-0.93727
Icheon	0.2795	1.53181	0.25086	0.2188	-1.33288	0.54437	0.26433	0.20341	0.44056	-0.29564
Namyangju	-0.40777	-0.68417	-0.13529	0.40967	-0.10657	-0.5041	-0.93768	0.06587	-0.65832	-0.3941
Osan	-0.05092	0.84987	0.31216	0.42626	0.66326	-0.73377	2.01604	0.03856	0.44884	-0.37605
Paju	0.49852	-0.28837	0.41712	-0.14634	-0.55532	-0.94346	-0.32935	0.77988	0.53337	-0.81583
Pocheon	0.55516	1.4045	-0.3843	-1.50178	-1.12012	0.28974	-0.49792	0.73134	0.6179	-0.92906
Pyeongtaek	-0.31148	0.67844	-0.04029	-0.47552	0.08299	-0.35931	0.5575	0.68987	0.20354	-0.0856
Seongnam	-0.64001	-1.39763	0.64697	0.88822	1.06558	1.14849	0.71142	-0.85143	-0.53899	0.99089
Siheung	-0.99119	-0.66022	0.31522	0.64756	0.56655	-1.27298	-0.38065	-0.31946	-0.27048	-0.19718
Suwon	-0.79483	-0.17619	0.34587	0.68905	1.02303	0.83894	1.99406	-1.11337	-0.18927	0.5347
Uijeongbu	-0.43609	-0.82409	-1.45082	0.90482	0.73676	0.77403	1.91343	-1.0982	-0.47269	0.09819
Uiwang	-1.01574	-0.80518	1.05611	0.54521	0.65165	1.00869	0.54284	-0.10707	-0.86219	1.09427
Yangju	1.26698	0.5234	-1.45082	-1.51008	-1.13172	-1.41777	-1.30415	0.14475	-0.30032	-0.8946
Yangpyeong	1.87117	1.44988	-0.23719	0.27136	-1.69652	-1.57754	-0.7911	1.37152	1.90738	-0.86835
Yeoju	1.15747	1.54063	0.41712	-0.49212	-1.61141	-0.94846	-0.38065	1.30882	1.88584	-0.99798
Yeoncheon	1.05929	0.67718	-0.13759	-1.29985	-0.12978	-0.80367	-1.09893	1.83573	0.87149	-0.92086
Yongin	-0.77406	0.54735	0.9182	-0.1989	-0.22263	-0.28442	-0.00686	-0.31137	-0.14452	-0.00847

Table B-1 (continued).

Area	x21	x22	x23	X24	x25	x26	x27	x28	x29	x30
Ansan	-1.39273	-1.15718	0.95669	0.62967	-4.52962	-1.49035	0.90298	0.98938	0.05202	0.71124
Anseong	1.11459	1.03305	-0.16271	0.08901	0.20029	0.68064	-0.13793	-0.34379	-0.22784	-0.03037
Anyang	-0.81317	-1.05454	-1.20308	0.53117	0.06163	0.31209	0.73309	0.74567	0.97597	-0.62818
Bucheon	-1.16434	-1.19978	-0.27684	-0.27031	-0.43139	0.62505	0.43966	0.47956	-0.39896	-0.57809
Dongducheon	0.1544	-0.21214	-3.03362	0.10692	0.46221	0.72557	-0.60021	-1.26989	-0.63961	-0.69881
Gapyeong	1.70643	1.69341	1.08399	-0.38113	-0.46221	1.40101	0.51894	0.08172	0.79356	-0.47792
Gimpo	0.40488	0.34364	1.97951	-0.60501	1.55609	-0.21334	-1.87998	-0.3069	-0.14228	0.7477
Goyang	-0.8058	-0.47939	1.32543	-0.85463	1.20174	0.59079	0.73206	0.75094	-0.31875	-0.98063
Gunpo	-0.96052	-0.69822	-0.03101	0.02185	1.1093	-1.14996	0.57145	0.54016	2.01817	-0.48115
Guri	-0.91631	-0.89187	-0.90458	-1.1065	-0.07703	0.80096	0.75266	0.44663	-3.87137	-0.94624
Gwacheon	-0.35886	-0.96352	-1.41818	-0.14158	-0.2157	-0.47072	0.99564	1.11321	-1.14704	-0.23533
Gwangju	0.50066	0.60507	-0.13637	0.88601	0.49302	0.15217	-2.83131	-0.78642	0.78999	0.31539
Gwangmyeong	-0.85001	-0.91704	-0.45682	1.25653	-0.01541	1.05377	0.90195	0.97357	-0.81846	-0.96448
Hanam	-0.54304	-0.34383	-0.69826	2.81584	0.03081	-0.50422	0.4376	0.61262	-0.25696	-1.07642
Hwaseong	1.29632	1.27318	-0.00028	-0.54233	0.60087	-1.26723	-1.14383	-0.75744	-0.45838	2.26669
Icheon	0.36805	0.02799	-1.19869	-0.86135	1.06307	-0.19659	-0.01026	0.22795	0.22968	1.5334
Namyangju	-0.60443	-0.369	-0.84312	0.23453	0.33895	0.80705	0.22757	0.40315	-0.58376	-0.82437
Osan	-0.3785	-0.5278	-0.01784	1.0931	-0.46221	-1.62513	-0.46534	-0.34115	-0.45838	0.93836
Paju	1.04583	0.96527	0.24554	-0.67329	-0.47761	0.53901	-0.40871	-0.36223	0.49528	-0.34359
Pocheon	0.82482	0.86457	0.307	-0.79643	0.16948	0.04785	-0.83187	-2.05899	0.59035	-0.27896
Pyeongtaek	0.16667	-0.10951	0.18409	-2.11283	-0.32354	-0.29558	-0.03497	0.03429	-0.59802	0.72301
Seongnam	-0.8672	-0.95771	0.16214	-0.53785	-0.16948	0.78801	0.99461	1.06183	0.62065	-1.0538
Siheung	-0.48901	-0.369	1.02693	1.40317	-0.35436	-2.06983	0.49423	0.59417	1.71276	1.46531
Suwon	-0.86229	-1.13781	-0.44365	-0.74605	0.27732	0.54434	0.7681	0.64818	0.24929	0.10442
Uijeongbu	-0.75914	-1.00613	-0.32074	-0.27927	-0.26192	0.80172	0.88547	0.70615	0.36931	-1.08011
Uiwang	-1.32397	-0.89768	0.5221	0.764	0.53924	-0.01231	0.49114	0.48747	0.42635	-0.37244
Yangju	0.23789	1.19959	0.96108	-1.65164	0.20029	-1.12636	-2.67173	-3.63324	0.36931	0.77933
Yangpyeong	2.09198	2.0323	1.47029	-0.05315	-0.26192	1.23805	0.50247	0.45453	0.0948	-0.82137
Yeoju	1.75554	1.56173	0.71086	0.67333	0.26192	0.48494	-0.01541	-0.36882	-0.08464	0.09127
Yeoncheon	1.47804	1.52106	0.51332	1.37183	-0.6779	1.07052	0.06696	-0.76271	-0.27656	-0.50077
Yongin	-0.0568	0.17129	-0.30318	-0.2636	0.15407	-2.24193	-0.38503	-0.3596	0.4935	2.69693

Table B-1 (continued).

Area	x31	x32	x33	X34	x35	x36	x37	x38
Ansan	1.06972	-1.73314	1.14548	-0.99056	0.53033	-0.73411	-1.33422	-0.21502
Anseong	-1.73787	1.34408	0.69575	-0.31266	1.20174	-0.14386	0.85814	-0.52656
Anyang	0.97357	-0.43136	0.35458	0.3498	-0.89685	-0.99644	-0.10436	-0.4292
Bucheon	0.69793	-0.30247	0.60891	-0.598	-0.58256	-1.1604	-0.93318	-0.11766
Dongducheon	-0.58265	0.16797	-0.02691	0.07355	0.27418	2.31552	1.33939	-0.37728
Gapyeong	-2.73713	0.10675	-3.14709	1.50932	1.02689	0.08568	1.63349	-0.1631
Gimpo	-0.61327	-0.58925	0.42281	-0.88606	0.59503	-0.20944	0.26995	-0.20853
Goyang	0.94508	-1.61714	-1.07524	1.01044	-1.17398	-0.73411	-0.74602	-0.43569
Gunpo	1.02413	-1.06292	-0.41151	-0.84789	-1.54115	-0.93086	-0.15783	0.73907
Guri	0.73426	-0.93403	-0.09515	0.73782	-0.94886	-0.11107	-0.61234	0.20036
Gwacheon	1.10746	-0.98236	-0.1975	1.3194	-1.98001	1.06943	0.18974	5.10061
Gwangju	-0.07412	0.17442	0.09405	-0.86698	0.66147	1.10222	-1.89567	0.29123
Gwangmyeong	0.33541	-0.08336	0.90356	0.56244	-1.51711	-1.1604	0.32342	0.42104
Hanam	0.45934	0.03908	0.23362	0.97681	-0.9069	-0.60294	-1.70852	-0.58497
Hwaseong	-0.20802	1.32153	2.73038	-1.27045	0.91062	-1.12761	-0.34498	-0.43569
Icheon	-0.06842	1.93697	0.05063	-0.67069	1.28698	0.18406	-0.07762	-0.48762
Namyangju	0.15522	-0.90503	-0.63172	-0.07003	-0.4016	0.21685	-1.14706	-0.23449
Osan	0.66873	0.61586	1.20131	-0.73794	-0.15331	0.64314	0.72446	0.53786
Paju	-0.2073	-0.08014	-1.20861	-0.36082	0.46345	0.21685	0.59078	-0.20853
Pocheon	-0.55843	0.3613	-0.41461	-0.30175	1.29091	0.83989	1.01856	-0.20204
Pyeongtaek	-0.28137	0.15508	0.65853	-0.18271	0.86953	-0.79969	0.56405	-0.07223
Seongnam	0.69509	-0.63758	-0.07654	0.90684	-0.7373	-0.93086	-0.71929	-0.20853
Siheung	0.69865	-1.10803	-0.41461	-1.36132	-0.77227	-0.53736	0.00259	-0.58497
Suwon	0.79124	0.34197	0.48174	0.09445	0.25451	-0.66853	-1.70852	0.10301
Uijeongbu	-0.15033	-0.33469	0.07234	1.94278	-0.61578	0.15126	-0.74602	-0.27343
Uiwang	0.89878	-0.96625	0.11576	-0.29994	-1.50225	0.08568	0.02932	-0.11117
Yangju	0.05123	-0.64081	0.02271	-1.42675	0.56399	0.70872	0.77793	-0.26694
Yangpyeong	-2.03202	1.46975	-0.05173	2.69157	1.26294	-0.47178	1.17898	-0.29291
Yeoju	-0.80557	1.80486	-0.01451	-0.13637	1.24633	1.9876	1.66022	-0.50709
Yeoncheon	-1.89243	1.53097	-1.88475	-0.0773	0.8232	2.47947	1.39286	-0.15661
Yongin	0.64309	1.03797	-0.14167	-0.77701	0.46783	-0.7669	-0.31825	-0.29291

APPENDIX C

Z-SCORES, 2000

Table C-1. Z-scores, 2000.

Area	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10
Ansan	0.32576	-0.30855	-1.90988	0.44023	-0.25379	-0.64338	-0.15748	1.56711	0.30484	-1.0407
Anseong	0.43897	0.71796	0.90947	0.65669	0.90769	0.04276	-0.96336	-0.21229	-0.31445	0.70426
Anyang	0.88045	-1.96105	0.90947	-0.92036	-1.74577	0.16583	0.59857	0.2255	0.75878	-0.90188
Bucheon	0.81801	-3.23702	0.90947	-1.26051	-0.15238	-1.97257	0.16275	-0.0287	1.06297	-0.09333
Dongducheon	0.61753	0.56525	-0.50021	-2.50771	-1.00307	1.12458	-0.96336	-0.52298	0.95533	-0.02758
Gapyeong	0.7311	0.76786	-1.90988	1.05868	-1.46409	2.05317	-0.96336	-0.72775	0.94831	2.4955
Gimpo	-1.08889	0.62149	0.90947	0.38869	1.60157	-1.21752	-0.76285	-0.30408	-1.24105	0.06619
Goyang	-0.71715	-0.03896	0.90947	0.63607	0.52178	-0.82122	0.51954	3.41007	0.17927	-0.93598
Gunpo	0.4229	-1.27111	0.90947	0.32685	-0.65096	-0.26739	1.04117	1.10814	0.61995	-0.63886
Guri	0.14464	-0.62141	-0.50021	-1.17805	-0.15989	-0.65261	1.10663	-0.31114	0.92569	-0.22728
Gwacheon	0.74096	0.23475	-1.90988	0.32685	-0.89039	0.86981	1.75269	-0.12756	0.76892	-0.42698
Gwangju	-1.06442	0.69619	-0.50021	0.5433	-0.78429	1.19596	-0.23621	-0.72775	-1.57566	-0.15178
Gwangmyeong	0.87059	-1.63965	0.90947	-1.42543	0.29925	-0.61815	1.32041	-0.32527	1.59568	-0.53536
Hanam	0.61899	0.41999	-0.50021	-1.36358	-0.26693	0.23968	1.77392	-0.46649	0.76268	-0.10916
Hwaseong	0.12091	0.70804	-0.50021	0.87314	1.43631	-0.58246	-0.55084	-0.69951	-1.0601	1.18038
Icheon	0.15048	0.67606	0.90947	0.88345	1.6673	-0.5683	-0.96336	-0.60065	-0.70911	0.9819
Namyangju	-1.05639	0.57104	0.90947	-0.1473	-0.69228	1.18611	0.58707	-0.6642	0.30796	-1.00052
Osan	-1.10532	0.09996	-0.50021	0.50207	1.48608	-1.01568	-0.96336	-0.60771	0.12701	-0.74237
Paju	0.27281	0.70804	-0.50021	-0.2916	0.70488	-0.02247	-0.96336	-0.64302	-0.30899	-0.08846
Pocheon	0.26149	0.73698	-0.50021	0.29592	-0.5674	1.20888	-0.96336	-0.6642	-0.63112	1.10854
Pyeongtaek	0.39953	0.56746	-0.50021	-0.52867	2.42972	-1.7295	-0.96336	1.61654	-0.10776	-0.13717
Seongnam	0.65003	-1.01751	-0.50021	-1.40481	-1.08476	0.01445	0.17602	2.16025	0.99199	-0.95303
Siheung	-3.95326	0.11016	0.90947	1.51221	0.63821	-1.06675	1.33574	0.81863	-0.58198	-0.77768
Suwon	-0.17853	-1.37833	0.90947	0.21346	0.25512	-1.47289	-0.07492	0.38084	0.21202	-0.61938
Uijeongbu	-0.23258	-0.43838	0.90947	-1.49758	-0.82185	0.65813	1.34577	-0.39588	1.02319	-1.15882
Uiwang	0.41888	0.16419	0.90947	0.16193	-0.55519	0.66243	1.75859	-0.27584	0.16211	-0.49395
Yangju	-0.16064	0.67937	0.90947	0.30623	0.00912	0.6649	-0.21203	-0.70657	-0.73875	-0.47812
Yangpyeong	0.62118	0.76041	-1.90988	1.34729	-0.82842	1.52395	-0.90556	-0.72775	0.76034	2.67572
Yeoju	0.54852	0.73919	0.90947	0.72884	0.5077	0.20706	-0.96336	-0.65714	-1.48362	1.06957
Yeoncheon	0.9334	0.76537	-0.50021	-0.05453	-0.44252	0.32398	-0.96336	-0.56535	-2.94528	1.51038
Yongin	-1.42996	0.60219	-0.50021	1.37821	-0.10074	0.50921	-0.94537	-0.32527	-0.76917	-0.25407

Table C-1 (continued).

Area	x11	x12	x13	x14	x15	x16	x17	x18	x19	x20
Ansan	-1.08304	-0.31223	0.53475	0.20424	0.91439	1.38533	0.94244	-2.48823	-0.28728	-0.16514
Anseong	0.13637	1.41758	0.01335	-0.97364	-1.05911	0.78511	-0.46395	1.33341	0.24115	-0.57061
Anyang	0.81359	-0.85345	1.06398	1.47305	0.95551	1.475	1.14446	-0.25751	0.2272	1.03593
Bucheon	0.77827	-0.79186	0.45722	0.78578	0.96465	-0.27032	0.32083	-0.86544	0.71973	0.10062
Dongducheon	-0.0319	0.10057	0.0475	-0.3921	0.5672	-1.26697	0.01003	0.41416	-0.66017	-1.0783
Gapyeong	1.45757	1.39268	-0.62826	-0.22716	-0.8581	-0.71995	-0.68151	0.85908	0.71176	-0.96756
Gimpo	-0.77559	-0.17987	0.40743	-0.9673	-0.68907	-0.06996	0.08773	0.34184	0.25312	-0.01693
Goyang	-0.60732	-1.54406	0.43944	0.81538	0.75907	1.18025	0.63164	0.28301	-0.56046	1.70546
Gunpo	0.28386	-1.03691	1.04904	0.92746	0.95551	1.10646	-0.33963	0.41783	-0.14968	1.34088
Guri	0.57677	-0.74992	0.39747	0.85979	0.91896	0.06948	1.94479	-1.33977	0.1574	0.02226
Gwacheon	0.43966	-0.91242	-3.92238	0.80904	0.8413	1.48701	-0.93016	-0.66933	-3.37211	3.11948
Gwangju	-0.90854	0.34038	-0.67876	-1.2845	-0.34188	-0.00303	-0.3474	-1.36796	0.32291	-0.63876
Gwangmyeong	1.29969	-0.98056	0.83991	1.11144	0.93267	1.17553	-0.1143	0.30262	-0.06793	0.51631
Hanam	0.98393	-0.61232	-0.67947	-0.77275	0.22458	0.12225	-0.72814	-2.71375	0.2591	-0.21796
Hwaseong	0.43551	1.01134	0.11365	-1.03708	-1.93622	-1.67327	-1.37306	1.03925	0.49839	-0.86875
Icheon	-0.10876	1.35599	0.17554	-0.2906	-1.10479	-0.68391	0.35191	0.42029	0.45053	-0.34914
Namyangju	-1.10797	-1.09326	0.39747	0.24019	0.04185	-1.53212	-1.34974	0.60414	-0.6841	-0.16003
Osan	-1.49643	0.56709	0.11365	0.90208	0.69512	-0.21369	0.77927	0.71199	-1.82072	-0.12766
Paju	0.25062	0.05732	-1.19376	-0.78121	-0.81699	0.28786	-0.40179	0.21682	0.73768	-0.91134
Pocheon	0.20284	1.32847	-0.68374	-1.8597	-1.57075	-1.1507	-0.26193	0.27566	-0.11379	-1.11067
Pyeongtaek	-0.71119	0.75842	0.0226	0.31632	0.04642	0.02915	0.65495	0.84314	-0.63424	-0.35425
Seongnam	0.66402	-1.01594	0.36475	1.29965	0.96465	1.22058	0.90359	-1.35448	-0.36504	1.26932
Siheung	-2.76985	-0.33188	0.75455	0.35861	0.67684	0.49723	-0.20754	0.62988	-0.19555	0.00181
Suwon	-0.60109	-0.34499	0.38751	1.04165	0.90983	0.01713	2.18566	-0.44136	0.34086	0.73268
Uijeongbu	0.234	-1.42481	0.04679	1.23198	0.71339	1.14035	1.97587	-0.30654	0.11752	0.12788
Uiwang	-0.21886	-0.7853	1.04904	0.77732	0.65857	0.70831	-0.77476	0.11264	0.13347	0.78208
Yangju	-0.27079	-0.05538	0.04608	-2.05425	-0.82156	-1.0516	-1.76156	-0.06508	-0.31918	-0.99823
Yangpyeong	1.16674	1.79499	-1.58498	-1.28873	-2.26057	-1.86762	-0.72814	0.93752	2.43862	-0.93008
Yeoju	0.58715	1.67967	0.24311	-0.49149	-1.7078	-0.62942	-1.07002	0.82231	1.05274	-1.06467
Yeoncheon	1.87096	1.25377	-0.94266	-1.09629	0.36163	-0.93704	-0.93793	1.13117	1.61507	-1.20777
Yongin	-1.4902	-0.0331	1.34922	0.36284	0.06469	-0.61741	0.53839	0.1727	-1.04702	0.98311

Table C-1 (continued).

Area	x21	x22	x23	x24	x25	x26	x27	x28	x29	x30
Ansan	-1.1305	-1.00469	0.93467	-0.40354	-3.32124	-1.49049	0.86037	0.93842	-0.98003	0.45757
Anseong	1.30325	1.21681	-0.73612	0.325	0.63485	0.68094	-0.3992	-0.73079	-0.31781	0.3193
Anyang	-0.66776	-0.96241	-1.48061	-1.14497	0.44594	0.31228	0.77607	0.79104	-0.9085	-0.39255
Bucheon	-0.88037	-0.98355	-0.55432	0.11116	0.31259	0.62486	0.35106	0.32743	-0.82446	-0.37508
Dongducheon	0.30524	0.1198	0.18152	0.30888	-1.34319	0.72536	-0.18423	-0.54555	0.66031	-0.48485
Gapyeong	1.92356	1.91856	1.39349	-1.6038	0.25702	1.40105	0.17333	-0.23955	0.98874	-0.5748
Gimpo	0.13265	0.29101	0.83944	1.1223	0.33481	-0.21351	-2.10414	-0.49643	-0.23198	0.29202
Goyang	-0.77782	-0.75739	0.7269	-0.56472	0.89044	0.59044	0.77396	0.68563	-0.6826	-0.88163
Gunpo	-0.61523	-0.81446	-0.08685	0.01016	0.82377	-1.15015	0.59904	0.67028	1.90427	-0.25851
Guri	-0.83785	-0.899	-1.7057	-0.52174	0.26814	0.80087	0.76202	0.7368	-3.32132	-0.64995
Gwacheon	-0.5427	-0.88209	-2.24242	-1.49097	0.36815	-0.47057	0.88355	1.06532	0.96847	-0.1454
Gwangju	-0.13749	0.08387	-1.45464	1.86481	1.1127	0.15238	-1.96013	-0.73386	1.02211	0.0953
Gwangmyeong	-0.71528	-0.78909	-0.04356	1.58435	0.36815	1.05349	0.87723	1.04485	-0.82684	-0.6946
Hanam	-0.40513	-0.5439	-0.13879	-1.11918	0.37926	-0.50388	0.63908	0.66311	-0.12827	-0.7644
Hwaseong	1.30325	1.53809	0.73556	0.52916	-1.27652	-1.2673	-1.68756	-1.37862	-0.45013	2.06664
Icheon	0.35276	0.10923	-0.05222	-1.28789	1.06825	-0.19685	0.07358	0.28138	-0.2588	3.64833
Namyangju	-0.80033	-0.46147	1.45409	0.58181	0.70153	0.80697	0.35387	0.51676	-0.26953	-0.81361
Osan	-0.52769	-0.30505	-0.14745	-0.30791	-0.0319	-1.62486	0.39532	0.22918	-0.45013	0.24337
Paju	0.89554	0.95471	0.80482	1.92928	-0.60976	0.53936	-0.79259	-0.74307	0.6615	-0.19605
Pocheon	0.60289	0.62709	-0.79672	-0.37023	0.15701	0.04744	-1.63839	-2.90865	0.33427	-0.23057
Pyeongtaek	0.30524	0.29101	-1.41136	0.59256	-0.40973	-0.29512	0.11713	0.01631	-1.11831	0.42295
Seongnam	-0.5602	-0.88209	0.19017	-1.28466	0.26814	0.7881	0.88285	1.0336	-0.01919	-0.70506
Siheung	-1.04045	-0.71723	2.12933	-0.47876	-1.76547	-2.06958	0.77888	0.87906	2.12123	0.1533
Suwon	-0.7528	-0.91169	-0.00894	0.64951	0.33481	0.54436	0.76764	0.6099	0.16916	-0.06446
Uijeongbu	-0.84035	-0.9138	-0.25999	-0.90642	0.71264	0.80198	0.90322	0.7368	0.23831	-0.88598
Uiwang	-1.08547	-1.13362	0.11226	0.05851	0.86822	-0.01196	0.59974	0.68358	0.65554	-0.44488
Yangju	0.10263	0.78561	0.4672	-0.04787	0.81266	-1.12683	-2.56357	-2.4655	0.23831	0.05756
Yangpyeong	2.21121	1.96928	0.79616	0.24118	-0.05413	1.23782	0.35528	0.28649	0.57746	-0.76262
Yeoju	1.78599	1.38802	0.71825	1.54782	0.44594	0.48551	-0.47506	-0.32245	-0.31185	-0.225
Yeoncheon	1.72596	1.82344	-0.79672	1.10081	-1.53211	1.07014	-0.03109	-1.29163	0.00108	-0.52704
Yongin	-0.63274	-0.15498	0.43257	-1.02462	-1.22096	-2.24225	-0.08729	-0.33984	0.55898	2.3207

Table C-1 (continued).

Area	x31	x32	x33	x34	x35	x36	x37	x38
Ansan	-0.11989	-1.19968	0.4874	-0.91501	0.4036	-0.3163	-2.28869	-0.18938
Anseong	-0.91776	1.49017	1.47252	-0.34291	1.03955	-0.63259	1.28095	-0.57345
Anyang	0.81465	-0.11487	0.5939	0.34209	-0.7707	-0.71886	-0.31541	0.28754
Bucheon	0.24272	0.20775	0.11466	-0.54714	-0.50251	-1.12142	-0.84753	-0.18938
Dongducheon	-1.27113	0.18356	-0.51546	0.48797	0.3686	2.18533	0.74883	-0.15984
Gapyeong	-3.72815	0.64732	-1.64701	0.93322	1.25203	0.77637	2.18999	-0.3582
Gimpo	0.63057	-0.97788	-0.52877	-1.30318	0.23352	-0.74761	-0.07152	0.03009
Goyang	0.87437	-1.34083	-1.16776	1.16409	-0.85746	-1.0064	-0.62581	-0.30333
Gunpo	0.4742	-0.76011	-0.18709	-0.55856	-1.46827	-0.17253	-0.11586	1.14853
Guri	-0.08357	0.03838	-0.46221	1.08671	-0.87028	0.23003	-0.02718	0.16515
Gwacheon	0.92977	-0.81657	-1.65588	0.20763	-1.96373	2.09907	1.12575	4.89214
Gwangju	0.20332	-0.17939	-1.00358	-1.13446	0.3824	0.54633	-0.07152	-0.33288
Gwangmyeong	0.28151	-0.03825	-0.01403	0.87614	-1.44658	-1.03516	0.63797	0.55343
Hanam	0.27104	0.57473	0.35872	1.18819	-0.76035	-0.20128	-0.44844	-0.53546
Hwaseong	0.39478	0.15936	2.96793	-2.03892	0.82362	-1.12142	-0.47061	-0.53968
Icheon	0.24026	2.00234	0.81134	-0.81733	1.27717	0.34505	-0.31541	-0.18516
Namyangju	0.47913	-0.70769	-0.8882	0.19114	-0.67062	-0.14377	-1.31313	-0.35398
Osan	0.58994	-0.1552	1.03321	-0.2465	-0.31814	-0.14377	0.15020	0.34663
Paju	-0.07618	0.19162	-0.26696	-0.35813	0.68509	0.37381	0.70449	-0.316
Pocheon	-0.68074	-0.09874	-0.56427	-0.81607	1.33978	0.43131	0.46060	-0.40041
Pyeongtaek	-0.19007	-0.21166	-0.10721	-0.19703	1.00553	-0.37381	0.28323	0.19469
Seongnam	0.23225	-0.1552	0.39865	1.13111	-0.57005	-0.83388	-0.75884	0.16515
Siheung	0.81896	-1.94978	-0.56427	-1.62158	-0.63956	-1.06391	-1.46834	-0.78447
Suwon	0.76663	-0.17133	0.64715	0.59072	0.19112	-0.63259	-1.20228	0.43948
Uijeongbu	0.32337	-0.21972	0.06141	1.5104	-0.77711	0.3163	-0.55930	-0.73805
Uiwang	1.096	-0.8206	-0.56871	0.39917	-1.70688	0.28754	0.46060	-0.03322
Yangju	0.21009	-1.26421	-1.37189	-1.65583	0.35923	0.08626	0.06151	-0.41729
Yangpyeong	-1.42628	1.69181	1.05096	1.29728	1.40239	-0.23003	2.03479	-0.42151
Yeoju	-0.51944	2.15558	1.3882	0.68586	1.36837	2.12782	0.57146	-0.40041
Yeoncheon	-1.81228	1.76843	-0.48883	1.23259	1.19928	2.04156	1.23661	-0.36664
Yongin	0.95194	0.07064	0.61609	-0.77167	-0.00903	-1.35145	-1.04707	-0.62409

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